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(54) A solar cell module having a specific back side covering material and a process for the production said solar cell module

(57) A solar cell module which comprises a stacked body a photovoltaic element interposed between a surface side covering material and a back side covering material having a foamed material layer, wherein said foamed material layer is a layer formed by foaming a nonfoamed material during the formation of said stacked body. And a building construction member having said solar cell module.

FIG. 1(A)

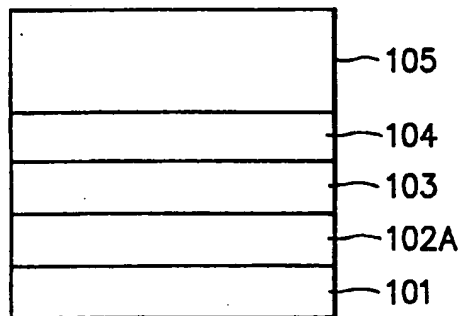
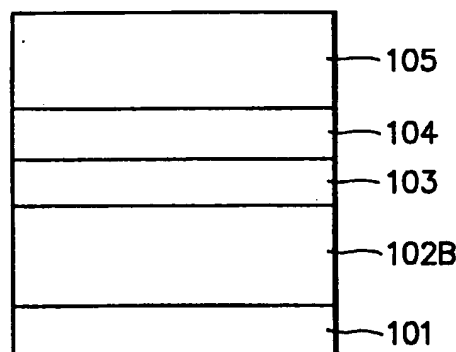


FIG. 1(B)



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## Description

BACKGROUND OF THE INVENTION5 Field of the Invention

The present invention relates to an improved, highly reliable solar cell module. More particularly, the present invention relates to an improved, highly reliable solar cell module comprising a photovoltaic element having a photoactive semiconductor layer as a photoelectric conversion member enclosed by a surface side covering material (which can be called a surface side covering member in other words) and a back side covering material (which can be called a back side covering member in other words) having a specific foamed material, which is hardly deteriorated with continuous irradiation of light, structurally excels in cushioning property, and is hardly deformed even upon the application of an external pressure thereon.

15 Related Background Art

Recently, a number of thin film solar cells have been proposed. A typical one of these thin film solar cells is an amorphous silicon (a-Si) thin film solar cell. As for the a-Si thin film solar cell, there is known a configuration in which an a-Si semiconductor film functioning as a photoelectric conversion element is disposed on an electrically conductive substrate and a transparent conductive layer is disposed said electrically conductive substrate. The thin film solar cell thus configured has advantages in that it excels in flexibility and is light.

There is known a solar cell module configured such that a plurality of such thin film solar cells having the above advantages are integrated in series connection into a module and the opposite faces of the module are covered by a surface side covering material and a back side covering material (these two covering materials will be occasionally referred to as covering material in the following) each comprising an organic resin material, which has advantages in that it can be bent as desired, is portable, and can be used in the case of enjoying a life of leisure in outdoor.

However, such solar cell module has such drawbacks as will be described in the following. That is, when the solar cell module is repeatedly bent, a problem is liable to entail in that the electric connection portions present at the bent portions are sometimes broken. In addition, as for the solar cell module, the covering material constituted by the organic resin material is usually thinned in order to make to be of light weight so that it can be easily carried. Because of this, the solar cell module is insufficient in terms of the physical strength, and therefore, when the solar cell module is placed on an uneven place such as sandy plain or sandy beach and somebody steps thereon, problems are liable to entail in that the solar cell contained in the solar cell module is damaged to lose its photoelectric conversion performance or/and the covering material is apertured to cause the generation of a leakage current.

In order to prevent the solar cell contained in the solar cell module from being damaged by such external pressure caused when somebody steps thereon, there is known a configuration in that the covering material to cover the rear side of the solar cell is designed to contain a foamed material. The solar cell module thus configured is capable of preventing the solar cell contained therein from being damaged by external pressure applied on the solar cell module when the solar cell module is placed on such uneven place as above described and somebody steps thereon. As the solar cell module having such configuration, there is known a light weight solar cell module which can float on water.

Now, in the case of an a-Si solar cell (an a-Si photovoltaic element), the photoelectric conversion efficiency is once reduced due to a so-called Staebler-Wronski deterioration to a certain level but it is recovered by way of heat annealing occurred during its continuous use in outdoor. And the reduction in the photoelectric conversion efficiency of the a-Si solar cell is slight even at a high temperature. Therefore, the a-Si solar cell is not necessary to have such complicated cooling structure as employed in the case of configuring a crystalline photovoltaic element into a module.

As for the a-Si solar cell, even when its photoelectric conversion member is of a thickness of several microns, it exhibits a desirable photoelectric conversion performance. Therefore, the production of an a-Si solar cell module can be conducted by disposing a given a-Si solar cell on an appropriate heat resistant support member. Such support member can include steel plates, metal plated-steel plates, stainless steel plate, and resin films composed of a heat resistant resin such as polyimide. The a-Si solar cell module thus produced excels in flexibility, and therefore, the solar cell (the photovoltaic element) contained the a-Si solar cell can be prevented from suffering a damage without using a rigid glass plate (having a thickness of 3 mm, for instance).

Particularly, in the case of producing a solar cell module using an a-Si solar cell (or an a-Si photovoltaic element), various covering configuration can be optionally employed. For instance, it is possible to cover the a-Si solar cell by a plastic film without using such glass plate. In the case of adding a rigidity to the solar cell module, it is possible to use an appropriate steel plate. The solar cell module having a steel plate or the like as the support member and having no glass plate on the surface thereof can be said that it is satisfactory in terms of a combination of rigidity, fire proof, incombustibility, and economy. And this solar cell module has a structure similar to that of a metallic roof of a building. Therefore, the solar cell module can be easily placed on such roof without using a complicated member and without

conducting a particular application work.

However, the steel plate has a high thermal conductivity of  $0.5 \text{ J/cm.s.K}$  and therefore, it releases heat to the open air through the member of fixing it. Because of this, the use of the steel plate is insufficient in order for the a-Si solar cell to be heat-annealed during the use of the solar cell module in outdoor. In order to eliminate the occurrence of this problem, it is desired to dispose a foamed material having thermal conductivity of about  $4 \times 10^{-4} \text{ J/cm.s.K}$  which is as lower as about 1000 times that of the steel plate between the a-Si solar cell and the steel plate.

Being different depending upon the use environment and the installation manner, in general, in the case of a solar cell module in which a foamed material having a thermal conductivity of  $1 \times 10^{-3} \text{ J/cm.s.K}$  or less is used, when the solar cell module is placed on a roof of a building, the temperature of the solar cell contained therein is heightened as much as about 10 to 30 °C over that in the case of a solar cell having no foamed material.

In general, as for a solar cell module which is free of this problem, there is considered a configuration having a heat insulator established by laminating the foamed material to the rear face of the support member so that the support member and an insulating member between the foamed material and the a-Si solar cell. However, this configuration is still problematic in that both the heat capacity and the thermal conductivity become great and an improvement provided is slight such that the temperature of the solar cell is heightened by only 10 to 20 °C.

Besides this, there is considered a configuration in which the foamed material is disposed between the support member and the insulating material. However, this configuration has a problem in that unless the foamed material has a high heat resistance, the pores present in the foamed material are broken during the process of covering an a-Si solar cell in order to produce a solar cell module. The reason for this is that as the covering process is performed by conducting heat treatment to fuse a filler material and conducting compression treatment to bond the covering material to the solar cell by means of the fused filler material, when the foamed material is intended to bond to the solar cell together with the covering material in the above, the foamed material is also heated and compressed and as a result, the pores present therein are broken. Especially in the case where the covering process is conducted by way of vacuum lamination, the air contained in the foamed material is released upon conducting the heating treatment and compression treatment and the foamed material is vacuumed, whereby the foamed material becomes to have no pore therein, or the resin constituting the foamed material is fused to make the foamed material into a state with no pore therein. The material thus resulted from the foamed material is never returned into a state having the original thickness even if it is cooled.

In this respect, it is difficult to cover the solar cell by the surface side covering material and the back side covering material having the foamed material into a desirable solar cell module at the same time by the above described covering process.

In order to eliminate the above problems, it is considered to use a foamed material excelling in heat resistance. But such foamed material is not desirably heat-deformed so as to fill the irregularities present at the solar cell even under high temperature condition in the covering process. Particularly in this respect, as for a solar cell (a photovoltaic element) used in the production of a solar cell module, wiring is conducted at the rear face thereof in order to make the solar cell module to have a large light receiving face as much as possible. Therefore, being somewhat different depending upon the situation, the rear face of the solar cell is provided with a plurality of irregularities in any case. In the case where a material having already foamed and which has flatness and excels especially in heat resistance is laminated to the uneven rear face of the solar cell, there entail other problems which will be described in the following. That is, in the case where the foamed material is one having been crosslinked, the irregularities present at the rear face of the solar cell cannot be sufficiently filled and therefore, the resulting solar cell module becomes to have a cavity therein. When this solar cell module accompanied by such cavity is subjected to the high temperature and high humidity dew concentration test prescribed in JIS-C-8917, water invades into the cavity when it is maintained under condition with a high temperature and a high humidity, and thereafter, when the solar cell module is cooled to a low temperature, the water invades into the cavities is frozen to expand in terms of the volume to cause layer separation at the expanded portion.

In order to eliminate the occurrence of the above problems, to use a foamed material having not crosslinked is considered. However, in this case, there entails a problem in that the foamed material is crushed during the covering process because it is not crosslinked. In order to prevent the foamed material from being crushed, it is considered to use, as the foamed material, a heat resistant foamed material composed of silicone resin, or polyester resin; especially polyethylene terephthalate or phenol resin, or a foamed material composed of polypropylene which is however slightly inferior to the formed foamed material in terms of the heat resistance. However, these foamed materials are difficult to heat-deform and therefore, the irregularities of the solar cell cannot be filled as desired by them. In addition, there is a problem in that the foamed materials excelling in heat resistance are mostly poor in flexibility. In fact, the foamed materials composed of polyacetal, phenol resin, or polyethylene terephthalate excel in heat resistance but inferior in flexibility. And in the case of a solar cell module obtained using any of these foamed materials, when it is bent at a curvature of 100 mm, the foamed material suffers from a crack or/and a wrinkle to be defective in the exterior appearance.

Now, as for a foamed material composed of a crosslinked silicone resin, it is considered that the foamed material is satisfactory in flexibility and heat resistance. The present inventors conducted experimental studies of this foamed material. As a result, it was found that the foamed material is crushed at a proportion of about 70% in terms of the layer thickness during the covering process by way of thermocompression treatment in order to produce a solar cell module.

There is known a solar cell module provided with a steel plate excelling in thermal conductivity as the support member and a heat insulation member comprising a heat resistant foamed material laminated on the outer surface of the steel plate, which can be maintained at a high temperature.

5 The production of this solar cell module is conducted in a manner of preparing a stacked body by conducting the foregoing covering process of laminating a given surface covering material on the light receiving face of a given solar cell (or a given photovoltaic element), and a back side covering material and said steel plate on the rear face of the solar cell, and bonding said foamed material to the steel plate of the resultant stacked body using an adhesive.

As for this solar cell module, because the foamed material is provided through the steel plate excelling in thermal conductivity, there are problems such that the temperature rising of the solar cell during the use is small and therefore, 10 desirable heat-annealing is not occurred in the solar cell; and the foamed material as the heat insulation member is liable to absorb moisture and therefore, the solar cell module is gradually deteriorated in terms of the thermal conductivity as it is repeatedly used in outdoor. Further, in the case where the lamination of the foamed material having thermal conductivity is intended to conduct during the covering process by way of thermocompression treatment, there entails a problem in that the irregularities present at the solar cell cannot be filled as desired and the resulting solar cell module 15 becomes inferior particularly in terms of the flexibility.

To use a foamed material having flexibility in the covering process can be considered. However, in this case, there entails a problem in that the pores in the foamed material are broken during the covering process. In the case of using a crosslinked foamed material having flexibility, it seems that the irregularities present at the solar cell would have been filled immediately at a stage immediately after the covering process, but in practice, as for the solar cell module obtained 20 in this case, when it is subjected to temperature cycle test or temperature and humidity cycle test, there is occurred a problem in that the filling state of the irregularities present at the solar cell becomes defective. As for the reason for this, it is considered such that the crosslinked foamed material is merely temporarily heat-deformed during the covering process, and this situation leads to cause layer separation at the interfacial portion having irregularities due to a stress generated because of changes in the environmental condition or successive relaxation in the internal stress of the residual foamed material. 25

When this solar cell module having the above defect in the filling state of the irregularities of the solar cell is practically used, there entails a problem in that water invades into the defective portion due to changes in environmental temperature and humidity wherein the water invaded is possibly frozen depending upon the use environment, whereby the foregoing layer separation further proceeds.

30 Now, in order to produce a solar cell module bonded with a given foamed material, it is necessary to conduct a lamination step of covering a given solar cell (or a given photovoltaic element) by a given surface side covering material and a given insulating material and a step of bonding the foamed material onto the insulating material using an adhesive or the like. In this case, in order for the foamed material to be bonded onto the insulating material without crushing the pores of the foamed material, the bonding step of the foamed material is necessary to be conducted at room temperature. Particularly, in the bonding step of the foamed material, application of the adhesive, drying of the adhesive applied, 35 lamination of the foamed material, and curing of the adhesive are necessary to be conducted. This manner is inferior in efficiency since these numerous steps are necessary to be conducted and it is inferior in productivity since foreign matters such as dust are liable to deposit upon drying the adhesive. Besides these problems, for this manner, there are further problems in that the curing of the adhesive is necessary to be conducted under pressure condition, and because 40 of this, it is necessary to use a particular pressing means, and in addition to this, the foamed material is sometimes laminated in a deviated state. Further, in the case where the adhesive used is of a solvent type, there are problems such that the application thereof is necessary to be conducted using a coating booth and for this, it is necessary to use a particular apparatus provided with an exhaust system. On the other hand, in the case where the adhesive is of an aqueous type such as an emulsion type adhesive, there are problems such that it usually takes time until the adhesive applied is dried, and in addition to this, the adhesion of the adhesive is usually insufficient and therefore, the foamed material laminated is liable to separate. 45

As the foamed material to be laminated, there is used one having a uniform thickness while disregarding the situation of the irregularities present at the rear face of the solar cell, and therefore, the portions of the laminated foamed material faced to the protruded portions of said irregularities are eventually protruded. This is not unacceptable in terms 50 of the exterior appearance. Besides this problem, a further problem is liable to entail in that the laminated foamed material itself does not follow the above protruded portions to cause the generation of a cavity at the interfacial portion thereof. When the solar cell module accompanied by such cavity at the interfacial portion of the layer comprised of the foamed material is subjected to the high temperature and high humidity dew concentration test prescribed in JIS-C-8917, water invades into the cavity when it is maintained under condition with a high temperature and a high humidity, 55 and thereafter, when the solar cell module is cooled to low temperature, the water invaded into the cavities is frozen to expand in terms of the volume to cause layer separation at the expanded portion.

Further, as for the solar cell module having the layer comprising the foamed material on the rear side which has been laminated at room temperature as above described, a problem is liable to entail in that the layer comprising the foamed material suffers from a distortion because the foamed material has not a sufficient heat history. Particularly, for

instance, when the solar cell module is subjected to temperature cycle test or temperature and humidity cycle test, there is often found the occurrence of a problem such that the layer comprising the foamed material is thermally expanded or thermally contracted to curl the solar cell module as a whole. In order to prevent the occurrence of this problem, there is considered a manner of subjecting the foamed material to heat treatment in advance prior to the practical use thereof.

5 In order to solve the foregoing problems, as above described, there is considered a manner of conducting the lamination of a previously foamed material in the foregoing covering process. However, in this case, unless the foamed material is highly heat resistant, a problem entails in that the pores in the foamed material are broken during the covering process. Particularly, as the covering process is performed by conducting heat treatment to fuse a filler material and conducting compression treatment to bond the covering material to the solar cell by means of the fused filler material, 10 when the foamed material is intended to bond to the solar cell together with the covering material in the above, the foamed material is also heated and compressed and as a result, the pores present therein are broken. Especially in the case where the covering process is conducted by way of vacuum lamination, the air contained in the foamed material is released upon conducting the heating treatment and compression treatment and the foamed material is vacuumed, whereby the foamed material becomes to have no pore therein, or the resin constituting the foamed material is fused 15 to make the foamed material into a state with no pore therein. The material thus resulted from the foamed material is never returned into a state having the original thickness even if it is cooled. Therefore, it is difficult to cover the solar cell by the surface side covering material and the back side covering material having the foamed material into a desirable solar cell module at the same time by the above described manner.

Incidentally, the present inventors conducted experimental studies by using a crosslinked silicone resin member, 20 which is considered to have flexibility and heat resistance, as the foamed material in the above. As a result, it was found that the crosslinked silicone resin member is crushed at a proportion of about 70% in terms of the layer thickness during the covering process.

#### SUMMARY OF THE INVENTION

25 The present invention has been accomplished as a result of extensive studies by the present inventors in order to solve the problems described in the above.

An object of the present invention to provide an improved, highly reliable solar cell module having a specific structure capable of always stably maintaining a photovoltaic element (or a solar cell) enclosed therein without being damaged even when external pressure is applied to thereto and without the photovoltaic element being deteriorated in terms of the photoelectric conversion efficiency even upon exposing to light irradiation over a long period of time. 30

Another object of the present invention is to provide an improved, highly reliable solar cell module having a photovoltaic element (or a solar cell) enclosed by a specific structure provided with a foamed material in a state free of not only unevenness based on the irregularities present at the photovoltaic element but also a cavity due to the foamed material while the irregularities present at the photovoltaic element being sufficiently filled in a desirably filled state and which excels especially in rear face protective ability, and said solar cell module is hardly damaged even when external pressure is applied to thereto and the photovoltaic element contained therein is hardly deteriorated in terms of the photoelectric conversion efficiency even upon exposing to light irradiation over a long period of time. 35

The present invention attains the above objects.

40 A typical embodiment of the solar cell module according to the present invention comprises a photovoltaic element (or a solar cell) having a photoactive semiconductor layer as a photoelectric conversion member, said photovoltaic element being enclosed by a surface side covering material disposed on the light receiving face side of said photovoltaic element and a back side covering material having a foamed material disposed to cover the rear face side of said photovoltaic element, wherein said foamed material comprises a stacked body comprising a foamed material and a fiber, 45 or a material comprising a foamed material incorporated with a fiber therein.

The present invention includes a process for the production of said solar cell module, characterized in that during a step of laminating a surface side covering material and a back side covering material to a photovoltaic element (or a solar cell) so as to enclose said photovoltaic element by said surface side covering material and said back side covering material by way of thermocompression treatment, a nonfoamed material as a constituent of the back side covering material is foamed to convert said nonfoamed material layer into a foamed material layer. 50

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIGs. 1(A) and 1(B) are schematic cross-sectional views illustrating an example of a solar cell module according to the present invention. 55

FIGs. 2(A) and 2(B) are schematic cross-sectional views illustrating another example of a solar cell module according to the present invention.

FIG. 3 is a schematic cross-sectional view illustrating an example of a photovoltaic element (or a solar cell) used in the present invention.

FIGs. 4(A) and 4(B) are schematic views illustrating an example of a lamination process employed in the present invention.

FIG. 5 is a schematic cross-sectional view illustrating a further example of a solar cell module according to the present invention.

5 FIGs. 6(A) is a schematic plan view of another example of a photovoltaic element (a solar cell) used in the present invention.

FIG. 6(B) is a schematic cross-sectional view, taken along the line A-A in FIG. 6(A).

FIG. 7 is a schematic view illustrating the rear face of the photovoltaic element shown in FIG. 6(A).

10 FIG. 8 is a schematic cross-sectional view of a solar cell module produced in Reference Example 1 which will be later described.

FIG. 9 is a schematic cross-sectional view illustrating a further example of a solar cell module according to the present invention.

FIG. 10 is a schematic cross-sectional view of a solar cell module produced in Reference Example 5 which will be later described.

15 FIG. 11 is a schematic cross-sectional view of a solar cell module produced in Reference Example 6 which will be later described.

FIG. 12 is a schematic cross-sectional view of a solar cell module used for the explanatory purpose.

FIG. 13 is a schematic cross-sectional view illustrating a further example of a solar cell module according to the present invention.

20 FIGs. 14 and 15 are schematic views respectively illustrating an embodiment when a solar cell module according to the present invention is used as a building construction material.

FIGs. 16(A) and 16(B) are schematic views illustrating an embodiment when a solar cell module according to the present invention is used as a roof material of a building.

## 25 DESCRIPTION OF THE INVENTION AND PREFERRED EMBODIMENTS

The present invention provides a highly reliable solar cell module having a photovoltaic element (or a solar cell) enclosed by a surface side covering material disposed on the light receiving face side of said photovoltaic element and a back side covering material having a foamed material disposed to cover the rear face side of said photovoltaic element, characterized in that said back side covering material comprises a specific structure provided with a specific member selected from the group consisting of a stacked body comprising a foamed material and a fiber and a material comprising a foamed material incorporated with a fiber therein (the specific member will be hereinafter referred to as fiber-bearing foamed material member).

30 In the solar cell module thus constituted according to the present invention, the above described structure (this structure will be hereinafter referred to as back side covering structure) as the back side covering material is in a state free of not only unevenness based on the irregularities present at the rear face of the photovoltaic element but also a cavity due to the foamed material while said irregularities of the photovoltaic element being sufficiently filled in a desirably filled state and which excels especially in rear face protective ability. Because of this, the solar cell module according to the present invention is hardly damaged even when external pressure is applied to thereto, and the photovoltaic element contained therein is hardly deteriorated in terms of the photoelectric conversion efficiency even upon exposing to light irradiation over a long period of time.

40 The fiber-bearing foamed material member of the back side covering structure functions to prevent the photovoltaic element enclosed in the solar cell module from being damaged due to external pressure applied to the solar cell module. Particularly, the use of the fiber-bearing foamed material member enables to obtain a desirable solar cell module which can be always stably maintained without the photovoltaic element (or the solar cell) enclosed therein being damaged even when the solar cell module is placed on an irregular surface of sandy plain, sandy beach or the like and weighty somebody erroneously steps on to apply a remarkable external pressure thereon. In the case where as the foamed material constituting the fiber-bearing foamed material member, a foamed material capable of readily deformed is used, there can be attained a highly reliable light weight solar cell module while reducing the amount of a hard resin to be used. Even in the case where a foamed material with a high expansion ratio is used as the foamed material, there can be attained a highly reliable light weight solar cell module, which is free of defects such as recession, cavity, or the like, with the use of the resin constituting the foamed material in a small amount.

55 In the case of a solar cell module having a support member (or a reinforcing support member), because of the use of the fiber-bearing foamed material member, a desirable adiathermic is provided so that the photoelectric conversion member of the photovoltaic element (or the solar cell) is effectively heat-annealed during the use, whereby the photovoltaic element is effectively prevented from being deteriorated due to light irradiation. And, as for this solar cell, when it is used as a roof material of a building or it is placed on a support table in outdoor, the fiber-bearing foamed material effectively functions as a heat insulation material.

Further, because of the use of the fiber-bearing foamed material, there can be attained a highly reliable solar cell

module which does not cause problems such as layer separation, isolation defect, and the like in temperature cycle test and temperature and humidity cycle test.

As previously described, the present invention includes a process for the production of a solar cell module comprising a photovoltaic element (or a solar cell) having a photoactive semiconductor layer as a photoelectric conversion member which is enclosed by a surface side covering material disposed on the light receiving face side of said photovoltaic element and a back side covering material having a foamed material disposed to cover the rear face side of said photovoltaic element, said process comprising a lamination step of laminating said surface side covering material and said back side covering material to said photovoltaic element so as to enclose said photovoltaic element by said surface side covering material and said back side covering material by way of thermocompression treatment, characterized in that during said lamination step, a nonfoamed material containing a foaming agent which is capable of using as a constituent of the back side covering material is foamed to form a foamed material layer in the back side covering material by decomposing said foaming agent.

The process according to the present invention enables to effectively produce a highly reliable solar cell module in a simple manner without conducting a separate step of laminating a foamed material.

In the process according to the present invention, as the foamed material layer is formed during the lamination step by way of thermocompression treatment, the foamed material layer resulted has a sufficient heat history and to be in a state free of the occurrence of thermal contraction. In fact, the solar cell module produced by the process according to the present invention is free of the occurrence of problems such as layer separation, isolation defect, and the like in temperature cycle test and temperature and humidity cycle test.

Further, in the process according to the present invention, when a stacked body comprising a nonfoamed material containing a foaming agent, and a fiber, or a material comprising a nonfoamed material containing a foaming agent and which is incorporated with a fiber therein is used as the foaming agent-containing nonfoamed material, there can be attained the formation of a desirable fiber-bearing foamed material layer. The resultant fiber-bearing foamed material layer is free of the occurrence of a recession, cavity or the like.

In the process according to the present invention, when the above lamination step is conducted in a face-up manner wherein the light receiving face of the photovoltaic element is faced upward, it is possible to surely form a skin layer at the foamed material layer. In this case, water invasion into the foamed material layer from the rear side is effectively prevented.

Further, in the process according to the present invention, when the above lamination step is conducted using a release member of  $1.0 \times 10^4 \text{ cm}^3/(\text{m}^2 \cdot 24 \text{ h} \cdot \text{atm})$  in nitrogen permeability, the expansion ratio of the foamed material layer formed is increased.

In the following, description will be described of embodiments of the present invention.

FIGs. 1(A) and 1(B) are schematic cross-sectional view illustrating the constitution of an example of a solar cell module according to the present invention.

FIGs. 2(A) and 2(B) are schematic cross-sectional view illustrating the constitution of another example of a solar cell module according to the present invention.

In FIGs. 1(A) and 1(B) and FIGs. 2(A) and 2(B), reference numeral 101 indicates a support member, reference numeral 102A a nonfoamed material layer, reference numeral 102B a foamed material layer (resulted from the nonfoamed material layer 102A), reference numeral 103 an insulating material layer, reference numeral 104 a photovoltaic element (or a solar cell), and reference numeral 105 a surface side covering material. In FIGs. 2(A) and 2(B), reference numeral 102C indicates a lower adhesive layer, and reference numeral 102D an upper adhesive layer.

The configuration shown in FIGs. 2(A) and 2(B) is a partial modification of that shown in FIGs. 1(A) and 1(B), wherein in the latter configuration, the support member 101 is omitted, two adhesive layers, namely, the lower adhesive layer 102C and the upper adhesive layer 102D, are used.

A stacked body shown in FIG. 1(A) comprising the nonfoamed material layer 102A, the insulating material layer 103, the photovoltaic element 104, and the surface side covering material 105 stacked in the named order on the support member 101 is subjected to thermocompression treatment wherein the nonfoamed material layer 102A is converted into a foamed material layer as the foamed material layer 102B shown in FIG. 1(B), whereby the stacked body shown in FIG. 1(A) is converted into a solar cell module having the configuration shown in FIG. 1(B) which comprises a stacked body comprising the foamed material layer 102B, the insulating material layer 103, the photovoltaic element 104, and the surface side covering material 105 laminated in the named order on the support member 101. In the stacked body shown in FIG. 1(A), the nonfoamed material layer 102A and the insulating material layer 103 constitutes a back side covering material. Similarly, in the stacked body shown in FIG. 1(B), the foamed material layer 102B and the insulating material layer 103 constitutes a back side covering material.

A stacked body shown in FIG. 2(A) comprising the nonfoamed material layer 102A, the lower adhesive layer 102C, the insulating material layer 103, the upper adhesive layer 102D, the photovoltaic element 104, and the surface side covering material 105 stacked in the named order is subjected to thermocompression treatment wherein the nonfoamed material layer 102A is converted into a foamed material layer as the foamed material layer 102B shown in FIG. 2(B), whereby the stacked body shown in FIG. 2(A) is converted into a solar cell module having the configuration shown

in FIG. 2(B) which comprises a stacked body comprising the foamed material layer 102B, the lower adhesive layer 102C, the insulating material layer 103, the upper adhesive layer 102D, the photovoltaic element 104, and the surface side covering material 105 laminated in the named order, wherein the lower adhesive layer 102C serves to improve the adhesion between the foamed material layer 102B and the insulating material layer 103 and the upper adhesive layer 102D serves to improve the adhesion between the insulating material layer 103 and the photovoltaic element 104.

In the stacked body shown in FIG. 1(A), the nonfoamed material layer 102A and the insulating material layer 103 constitute a back side covering material. Similarly, in the stacked body shown in FIG. 1(B), the foamed material layer 102B and the insulating material layer 103 constitute a back side covering material.

In the stacked body shown in FIG. 2(A), the nonfoamed material layer 102A, the lower adhesive layer 102C, the insulating material layer 103, and the upper adhesive layer 102D constitute a back side covering material. Similarly, in the stacked body shown in FIG. 2(B), the foamed material layer 102B, the lower adhesive layer 102C, the insulating material layer 103, and the upper adhesive layer 102D constitute a back side covering material.

In not only the solar cell module shown in FIG. 1(B) but also the solar cell module shown in FIG. 2(B), light is impinged through the surface side covering material 105 side, and the light impinged passes through the surface side covering material 105 to arrive in the photovoltaic element 104 to generate an electromotive force, which is outputted through outputting terminals (not shown).

The support member 101 serves as a reinforcing member and therefore, it is not always necessary to be disposed. The support member 101 may be optionally disposed depending upon the situation.

Now, there are two kinds of a solar cell module in terms of rigidity, namely, a permanent type solar cell module which is permanently used by disposing in outdoor, and a portable type solar cell module excelling in flexibility. The permanent type solar cell module is used by integrating with a building member, mounting on a frame, or mounting on a support table though a frame. Therefore, as for the permanent type solar cell module, it is required to have a sufficient rigidity. Particularly, it is generally advised that the permanent type solar cell module should have a rigidity such that it can endure against a wind speed of 30 to 40 m/sec.

In the present invention, when the solar cell module has a fluororesin film as the surface side covering material 105 without disposing a glass plate thereon, it is effective for the solar cell to be provided with the support member 101 (the reinforcing member) in order to meet the above requirement.

In the present invention, the support member 101 can include steel members, glass fiber reinforced plastic members, hard plastic members, and timber members.

When the solar cell module is of the type that it is used by integrating with a building member, it is desired to be configured such that an improvement in rigidity can be readily attained by subjecting to bending processing so that it can be readily engaged in a channel of a member to which the solar module is intended to install. For this purpose, a steel member or stainless steel member is desired to be used as the support member. The solar cell having such steel member as the support member can be desirably used as a roof member of a building since the steel member is not only hardly melted when exposed to flame but also it is hardly deformed. In this case, it is desired for the support member to excel in rust proof and also in weatherability. In order for the steel member as the support member to have a desirable rust proof and weatherability, it is possible to coat the steel member with an anticorrosion paint excelling in weatherability.

In the case where the adhesion between the foamed material layer and the support member is not sufficient, it is possible to dispose an adhesive layer or a binder layer between the foamed material layer and the support member upon the lamination of the support member to the foamed material layer. The adhesive layer may comprise a thermoplastic resin such as ethylene-vinyl acetate copolymer. The binder layer may comprise an emulsion paint.

As for the above described portable type solar cell module, it is suitable for use in a place where no electric cable system is available, or for use as a power supply source for batteries used in automobiles or yachts. For these use purposes, the solar cell module is required to be flexible and light. Particularly, it is desired to be configured such that it is light so that it can be easily carried and that when not used, it can be easily folded or rounded in order to store.

In the case where the portable type solar cell module is use such way as above described, the back side covering material thereof is often exposed to severe environmental condition. For instance, it is carried while dragging on the ground or some body erroneously steps thereon. In order to prevent the photovoltaic element of the solar cell module from being damaged due to external pressure applied in such case, the foamed material layer is disposed in the back side covering material.

In the case where the foamed material layer is insufficient in abrasion resistance and shock resistance, it is possible for the foamed material layer to have a protective film on the rear face thereof. As such protective film, there can be mentioned films having weatherability, flexibility, water resistance, gasoline resistance, and plasticizer transfer resistance. Specific examples of the constituent of the film usable as the protective film are low density polyethylene, polyethylene copolymer, ethylene-vinyl acetate copolymer with vinyl acetate content of 30 wt.% or less, plasticizer-containing polyvinyl chloride, polyester, and vinyl fluoride.

In the case where the adhesion between the foamed material layer and the protective film layer is not sufficient, it is possible to dispose an adhesive layer or a binder layer between the foamed material layer and the support member



upon the lamination of the protective film layer to the foamed material layer. The adhesive layer may comprise a thermoplastic resin such as ethylene-vinyl acetate copolymer, ethylene-ethylacrylate copolymer, polyvinyl butyral, silicone resin, acrylic resin, and epoxy resin. The binder layer may comprise an emulsion paint.

5 The use of the protective film layer provides an advantage in the production of a solar cell module, in addition to the advantage of protecting the solar cell module. That is, the use of the protective film layer prevents the gas, which is generated when the foaming agent used upon the formation of the foamed material layer is decomposed, from leaking to the outside.

10 In the present invention, the foregoing adhesive layer (as the lower adhesive material layer 102C shown in FIG. 2(A)) may be disposed between the nonfoamed material layer 102A and the insulating material layer 103 or it may be disposed between the insulating material layer 103 and the photovoltaic element 104 (as the upper adhesive layer 102D shown in FIG. 2(A)). By this, the resultant stacked body as a solar cell module has an improved adhesion between the foamed material layer 102B and the insulating material layer 103 or between the insulating material layer 103 and the photovoltaic element 104.

15 As for the adhesive used as the above adhesive layer, it is desired to be in a solution state at the initial stage of conducting the thermocompressing treatment and to be in a crosslinked state after the completion of the thermocompression treatment. The crosslinking of the adhesive is desired to be conducted by using a crosslinking agent such as organic peroxide. By crosslinking the adhesive using the crosslinking agent, the cohesive force of the resin constituting the adhesive is increased to prevent the adhesive resin from being broken within the layer. In this case, when the adhesive layer comprising the crosslinking agent-containing adhesive is present between the support member and the  
20 foamed material layer, there is provided a covalent bond not only at the interface with the foamed material layer but also at the interface with the support member, whereby the adhesion between the foamed material layer and the support member is improved.

25 Since the adhesive layer used in the back side covering material is situated on the rear side of the photovoltaic element (see, FIGs. 2(A) and 2(B)), it may be opaque. The foregoing resin used as the adhesive layer may contain a crosslinking agent, a thermal oxidation preventive agent, or the like for improving the heat resistant. In order to improve the light stability of the adhesive layer, the resin may contain an UV absorber, a light oxidation preventive agent, or the like.

30 In the case where the adhesion of the adhesive layer with the photovoltaic element (see, FIGs. 2(A) and 2(B)) is insufficient, the resin constituting the adhesive layer may contain a silane coupling agent, a titanate coupling agent, or the like in order to improve the adhesion. Further, in order to ensure the photovoltaic element such that it is definitely electrically isolated from the outside, it is desired to dispose an insulating resin layer in the adhesive layer. Such insulating resin layer may comprise a film composed of nylon, polyethylene, polyester, or polystyrene.

In the following, description will be made of the nonfoamed material layer 102A.

35 The nonfoamed material layer 102A comprises a resin containing a foaming agent. The foaming agent contained in the nonfoamed material layer 102A is decomposed to produce gas during the thermocompression treatment of the stacked body shown in FIG. 1(A) or 2(A) to cause the formation of a foamed material layer as the foamed material layer 102B, whereby a stacked body of the configuration shown in FIG. 1(B) or 2(B) as a solar cell module is afforded.

40 The resin constituting the nonfoamed material layer is required to have a desirable filling property. Particularly in this respect, it is desired to have a flowability of 1 dg/minute to 400 dg/minute in terms of melt flow rate in the flowability standard of ASTM4-1238. When a resin having a melt flow rate of less than 1 dg/minute is used as the resin constituting the nonfoamed material layer, there cannot be attained a desirable flowability such that the irregularities present at the rear face of the photovoltaic element are filled in a desirable state. By raising the temperature in the thermocompression treatment, there can be attained a desirable flowability. But in this case, there entails a drawback in that a filler (or a filler layer) used in the surface side covering material is yellowed to reduce the photoelectric conversion efficiency of the  
45 solar cell module. On the other hand, when a resin having a melt flow rate of beyond 400 dg/minute is used as the resin constituting the nonfoamed material layer, the gas generated from the foaming agent is leaked to the outside without being trapped within the resin.

50 The cellular structure of the foamed layer resulted by the gas generated from the foaming agent contained in the nonfoamed material layer is required to have a sufficient heat resistance such that it is not broken with the high temperature employed in the thermocompression treatment. In view of this, the resin constituting the nonfoamed material layer is desired to be capable of being crosslinked.

55 In any case, the nonfoamed material layer 102A is required to be capable of being converted into a foamed material layer as the foamed material layer 102B during the thermocompression treatment, and it is also required to have a sufficient adhesion with the insulating material layer 103 and also with the support member 101. In addition, the resin constituting the nonfoamed material layer is required to have a certain quantity of a polar group in the molecule. As the resin constituting the nonfoamed material layer, any resin may be used as long as the above requirements are fulfilled. Specific examples of such resin are natural rubber, styrene butadiene rubber (SBR), chloroprene rubber (CR), ethylene propylene rubber (EPR), ethylene-vinyl acetate copolymer, and ethylene-acrylic ester copolymers such as ethylene ethyl acrylate. In the case of separately using an adhesive, polyethylene, polypropylene, polystyrene, and ABS resin are also

usable.

It is desired for the resin constituting the nonfoamed material layer 102A to contain a crosslinking agent, a filler, or the like, in addition to the foaming agent.

The conversion of the nonfoamed material layer 102A into a foamed material layer as the foamed material layer 102B may be conducted by (a) a manner of utilizing gas generated by way of chemical reaction, (b) a manner of incorporating a volatile solvent having a low boiling point into the resin and vaporizing the solvent, (c) a manner of incorporating a micro balloon filler into the resin, or (d) a manner of incorporating a soluble material into the resin and eluting the soluble material.

Of these manners, the manner (a) is the most appropriate. In the manner (a), it is desired to use, as the foaming agent, an organic foaming agent capable of readily providing a closed wall cell foam. The organic foaming agent contained in the resin constituting the nonfoamed material layer 102A is one that is decomposed to generate gas when subjected to heat treatment, wherein the resin is softened, expanded due to the gas generated therein, and cured to cause the formation of a foamed material layer as the foamed material layer 102B.

Besides the organic foaming agent, it is possible to use an inorganic foaming agent. Such inorganic foaming agent can include sodium bicarbonate, ammonium bicarbonate, ammonium carbonate, and azide compounds.

Other than these compounds, there can be also mentioned sodium borohydroxide and light metals which are capable of generating gas (specifically, hydrogen gas) when subjected to heat treatment. But the temperature at which they generate the gas (that is, hydrogen gas) is 400 °C or above and the hydrogen gas generated is dangerous. Therefore, these are not appropriate to be used.

In the case of using the above mentioned carbonate compounds as the inorganic foaming agent, continuous pores are readily formed in the resin constituting the nonfoamed material layer. Therefore, a due care should be made so that no water is invaded into the resulting foamed material layer by conducting water proof treatment, or the like.

In the following, further description will be made of the organic foaming agent. The organic foaming agent is desired to be such an organic foaming agent that can sharply generate gas substantially comprising nitrogen at an appropriate gas generation rate by way of heat decomposition to cause the formation of fine and uniform closed wall cell foams in the resin constituting the nonfoamed material layer. In the case where the organic foaming agent is of a heat decomposition temperature which is greatly different from the temperature employed in the thermocompression treatment of the stacked body having the nonfoamed material layer, it is possible to use a foaming accelerating agent.

In any case, it is desired for the the organic foaming to have a heat decomposition temperature such that the foregoing gas (substantially comprising nitrogen) is generated when the resin constituting the nonfoamed material layer is softened and crosslinking reaction is being proceeded in the resin, and the heat decomposition temperature is higher than the softening point of the resin and is of a degree of -40 °C to +40 °C of the one hour-half life temperature of a crosslinking agent comprising an organic peroxide which will be described later.

The formation of the foamed material layer from the nonfoamed material layer is desired to be conducted in such a manner that the crosslinking of the resin constituting the nonfoamed material layer is preferentially proceeded and the gas from the foaming agent is generated.

The amount of any of the inorganic foaming agent and the organic foaming agent added is desired to be in the range of 0.1 to 30 parts by weight versus 100 parts by weight of the resin constituting the nonfoamed material.

As previously described, in the case of the portable type solar cell module, it is required for the nonfoamed material layer (which is converted into the foamed material layer during the thermocompression treatment) to have not only a sufficient heat resistance during the thermocompression treatment but also a sufficient adhesion with the insulating material layer. In addition, when the foamed material layer (resulted from the nonfoamed material layer) is situated on the rearmost side of the back side covering material of the solar cell module, it is required to have a sufficient abrasion resistance.

In order to meet these requirements, it is desired for the foamed material layer to be crosslinked. In order to make the foamed material layer to be in a crosslinked state, it is possible to employ radical crosslinking or ion crosslinking by way of chemical reaction with the use of a curing agent. Of these, the radical crosslinking is the most appropriate in view of desirably meeting the above requirements.

The radical crosslinking can include electron beam crosslinking, X-ray crosslinking, and chemical crosslinking. Of these, the chemical crosslinking is the most appropriate in view of an equipment used therefor. In general, the chemical crosslinking is conducted using an organic peroxide as a crosslinking agent.

The crosslinking of the resin constituting the nonfoamed material layer by the chemical crosslinking using the organic peroxide as the crosslinking agent is performed by way of pulling hydrogen atoms in the resin by virtue of free radicals generated from the organic peroxide to form C-C bonds. In order to make the organic peroxide generate such free radicals upon crosslinking the resin, the organic peroxide is desired to be activated by means of a thermal decomposition process, redox decomposition process, or ion decomposition process. Of these processes, the thermal decomposition process is the most appropriate.

As for the amount of the organic peroxide as the crosslinking agent to be added to the resin, it is preferably in the range of 0.1 to 5 wt.% versus the amount of the resin.

Now, as for an organic peroxide usable as a crosslinking agent, it is general to define it by its one hour-half life temperature.

As for the organic peroxide usable as the crosslinking agent in the present invention, there is no particular limitation in terms of the one hour-half life temperature. However, in the case where the resin constituting the nonfoamed material layer is a resin principally comprising an olefin resin, as the temperature employed in the thermocompression treatment is about 90 to 150 °C, it is desired to use those organic peroxides having a one hour-half life temperature of 100 to 170 °C as the crosslinking agent. There is no decisive limitation for the relationship between the decomposition temperature of the foaming agent and that of the crosslinking agent. However, it is desired that the one hour-half life temperature of the organic peroxide as the crosslinking agent is higher than the decomposition temperature of the foaming agent.

It is possible for the nonfoamed material layer to contain a filler capable of serving not only as a nucleus material of adjusting the number of pores formed therein but also as an extender. By using such filler in a relatively large amount, the number of a pore formed is increased to result in forming a dense foamed material layer from the nonfoamed material layer. As for the amount of the filler, the addition thereof in an amount of about 1 wt. % versus the amount of the resin constituting the nonfoamed material layer is sufficient. The addition of the filler in an amount which is greater than said amount is not effective in increasing the number of a pore formed. Separately, as the extender, it is possible to add an appropriate extender.

Specific examples of such filler are calcium carbonate, clay, talc, magnesium oxide, zinc oxide, carbon black, silicon dioxide, titanium oxide, plastic in fine particle form, orthoboric acid, alkali metal salts of aliphatic acids, citric acid, and sodium hydrogencarbonate.

As for the filling property of the back side covering material which is a feature of the present invention, it is decided depending on the formulation of the nonfoamed material layer and the conditions in the covering process by way of thermocompression treatment. Particularly in this respect, the nonfoamed material layer is heated to a temperature at which the resin constituting the nonfoamed material layer exhibits a flowability, wherein the resin is fused to fill the irregularities present at the rear face of the photovoltaic element, then the foaming agent contained in the resin constituting the nonfoamed material layer is decomposed to generate gas to form minute pores in the resin whereby causing the formation of a foamed material layer. In this case, when the generation of the gas from the foaming agent is terminated and the resultant foamed material layer is still maintained in a heated state, there is a tendency that the foamed structure of the foamed material layer is broken. In order to prevent the occurrence of this problem, it is desired to make such that the resin is crosslinked during the above process of forming the foamed material layer.

The term "irregularities" present at the rear face of the photovoltaic element in the present invention is meant to include irregularities of the back side covering material.

Now, in the case of a solar cell module having a back side covering material comprising an insulating material layer, the irregularities present at the rear face of the photovoltaic element cannot be filled to be in a smooth state only by the insulating material layer, wherein the solar cell module is unavoidably accompanied by irregularities caused at the residual insulating material layer.

The foamed material layer in the present invention is desired to be of a closed cell wall foam structure which hardly absorbs water, in order to prevent the foamed material layer from becoming to have an increased thermal conductivity due to water invasion thereinto.

In the case of the foregoing permanent type solar cell module, as previously described, the foamed material layer of the back side covering material serves to protect the rear face of the photovoltaic element thereof. Further, the use of the foamed material layer as the back side covering material makes the resulting solar cell module such that it can float on water. The foamed material layer in this case is also desired to be of a closed cell wall foam structure which hardly absorbs water.

As for the thickness of the foamed material layer, it is different depending on the use environment. In the case where the solar cell module is used as a roof member of a building or it is used by placing on a support table, the thickness of the foamed material layer is desired to be in the range of 0.5 to 15 mm. In the case where the thickness of the foamed material layer is less than 0.5 mm, there cannot be attained a desirable temperature rising effect for the photovoltaic element, wherein the photovoltaic element is not sufficiently heat-annealed during the use and therefore, there cannot be expected a desirable recovery for the deterioration in the photoelectric conversion efficiency of the photovoltaic element due to the Staebler-Wronski deterioration. On the other hand, in the case where the thickness of the foamed material layer is beyond 15 mm, the foamed material layer is liable to suffer from significant thermal expansion or significant thermal contraction to cause layer separation at the interface with the adjacent member in temperature cycle test, temperature and humidity cycle test, and the like.

In the case of the foregoing portable type solar cell module, as previously described, it is required for the foamed material layer to have a sufficient protective ability of preventing the photovoltaic element from being damaged due to external pressure applied to thereto.

By the way, in the case of a portable solar cell module, there is an occasion of suffering from external pressure applied thereto, for instance, when the solar cell module is stepped by shoes of somebody or when it is dragged on the ground. Particularly in the former case, when the solar cell module is present on an irregular surface of soil or sand and

it is stepped by the shoes, the solar cell module suffers from a force of deforming the photovoltaic element contained therein, which is caused from the rear side of the solar cell module. In order to relax such stress, the solar cell module is desired to have a back side covering material comprising a material having an excellent buffering property but not a highly rigid material.

5 The foamed material layer as the back side covering material in the present invention effectively prevents the occurrence of the above problems while satisfying the above described situation.

The foamed material layer in the portable type solar cell module in the present invention is desired to have a thickness which is greater than the size of a grain of sand or that of a lump of soil. However, in the case where the foamed material layer is excessively thick, problems of causing curling and the like are liable to occur. Therefore, in general, the  
10 thickness of the foamed material layer in the case of the portable type solar cell module in the present invention is desired to be in the range of 1 to 15 mm.

In the case of the portable type solar cell module in the present invention, as well as in the case of the permanent type solar cell module, it may have the foregoing support member or/and the foregoing protective film on the foamed material layer.

15 As previously described, the resin constituting the nonfoamed material layer is fluidized by the gas generated from the foaming agent during the thermocompression treatment. During the thermocompression treatment, as the nonfoamed material layer will have irregularities based on the irregularities present at the rear face of the photovoltaic element, the recessed portions of the nonfoamed material layer are less pressed and because of this, the gas generated from the foaming agent is liable to converge at such less pressed portion. In this case, it is considered that the gas thus  
20 converged would make the resin present nearby to crosswise fluidize thereby causing a recession or cavity in the resulting foamed material layer. In order to prevent the occurrence of such recession or cavity, it is necessary to make such that during the thermocompression treatment, the resin constituting the nonfoamed material layer is heat-fused to fill the irregularities present at the rear face of the photovoltaic element and that when the foaming agent is decomposed to generate the gas of converting the nonfoamed material layer into a foamed material layer, the resin is partly pre-  
25 vented from being fluidized. For this purpose, it is desired to incorporate an appropriate fiber into the nonfoamed material layer which is to be converted into the foamed material layer. The fiber contained in the nonfoamed material layer is partly or entirely is immersed in the resin constituting the nonfoamed material layer when the foaming agent generates the gas at the stage after the resin of the nonfoamed material layer has been heat-fused to fill the irregularities present at the rear face of the photovoltaic element in the thermocompression treatment, whereby the resin of the nonfoamed  
30 material layer is prevented from being crosswise fluidized as above described. By this, even if the nonfoamed material layer has a less pressured portion, the gas generated from the foaming agent is hardly converged at such less pressured portion to prevent the resin of the nonfoamed material layer from being crosswise fluidized. Hence, there can be attained the formation of a desirable foamed material layer free of a recession or cavity which is liable to occur when the expansion ratio is high.

35 Description will be made of the fiber used in the present invention. As the fiber, any fibers may be optionally used with no regard to their configuration as long as they are satisfactory in terms of the heat resistance, weatherability, and adhesion.

As apparent from the above description, the fiber used in the present invention is necessary to have a performance of preventing the resin constituting the nonfoamed material layer from being fluidized as above described. For this purpose, the fiber is required to have a sufficient heat resistance such that it is not melted in the thermocompression treatment. In the thermocompression treatment, the material of covering the photovoltaic element (specifically, the back side covering material in this case) is exposed to a temperature of 120 to 180 °C in general. And the period of time during which the thermocompression treatment is conducted is 2 hours or less in terms of including the period of time required to raise the temperature to a maximum temperature. For instance, when the maximum temperature is 180 °C, the  
45 period of time for maintaining at this maximum temperature is 10 minutes or less. The fiber is satisfactory as long as it has a heat resistance which can endure against this temperature condition.

There are commercially available fibers composed of inorganic compounds (these fibers will be hereinafter referred to as inorganic fiber) and fibers composed of organic compounds (these fibers will be hereinafter referred to as organic fiber). These inorganic fibers are mostly heat resistant.

50 As for these organic fibers, they can be expressed by the relationship based on the following equation.  
 $T_m = \Delta H_m / \Delta S_m$ , with  $T_m$  being a melting point,  $\Delta H_m$  being a melting enthalpy, and  $\Delta S_m$  being a melting entropy.

The heat resistance of the organic fiber may be increased by enlarging the  $\Delta H_m$  and diminishing the  $\Delta S_m$ .

To enlarge the  $\Delta H_m$  may be accomplished by increasing the intermolecular force. The intermolecular force may be increased by increasing the dipole-dipole interaction or the number of a hydrogen bond. To increase the dipole-dipole  
55 interaction may be accomplished by introducing an amide group, imide group, nitrile group, or halogenated hydrocarbon group respectively having a strong polarity into the molecule. To increase the number of a hydrogen bond may be accomplished by introducing an ether group, amide group, or urethane group into the molecule. To diminish the  $\Delta S_m$  may be accomplished by increasing the symmetric property of the molecule or making the molecule have a stiff portion comprising, for example, an aromatic ring.

Even in the case where the organic fiber is such that has a molecular structure which is low in heat resistance, the organic fiber may be made to have an improved heat resistance by crosslinking it. Further, by causing molecular-molecular bonding by way of covalent binding in the molecule, the molecular motion is controlled and as a result, there is provided an improvement in the heat resistance.

5 In the present invention, the organic fiber is occasionally contained in the foamed material layer in a state that is exposed at the surface of the foamed material layer. The fiber in this case is necessary to excel in weatherability, water resistance, and gasoline resistance. Particularly, in the case of the portable type solar cell module, the organic fiber is necessary to excel in these properties because the solar cell module will be used under various environmental conditions. Further, in the case of the portable type solar cell module, since it will be used by placing in various places or by  
10 placing on a curved face, the organic fiber is necessary also to excel in flexibility. Further in addition, the organic fiber is desired to exhibit an excellent adhesion with the foamed material layer.

As such organic fiber excelling in the adhesion with the foamed material layer, there can be mentioned those organic resin fibers having a polar group such as ester group, carbonyl group, or hydroxyl group.

In the case where the fiber is such that is inferior in the adhesion with the foamed material layer, it may be made to  
15 have an improved adhesion by coating it with an adhesion accelerating agent such as a silane coupling agent or by treating it so as to have a polarity at the surface thereof, for instance, by way of corona discharging treatment.

Specific examples of the fiber usable in the present invention are glass fiber, polyester fiber, polypropylene fiber, rayon fiber, nylon fiber, and fluororesin fiber.

The fiber used in the present invention is desired to have a sufficient fiber length in order to prevent the resin of the  
20 nonfoamed material layer from being undesirably fluidized as above described.

In the case of using a monofilament as the fiber, it is desired to be previously incorporated into the resin constituting the nonfoamed material layer. In this case, to lay the monofilament as the fiber under the nonfoamed material layer is not necessary to be conducted. However, in any case, the fiber length of the monofilament is an important factor. Particularly, the fiber length of the monofilament is desired to be in the range of 10 to 50 mm. When the monofilament is of  
25 a fiber length of less than 10 mm, the monofilament fluidizes together with the resin of the nonfoamed material layer and because of this, it is difficult to prevent the fluidization of the resin as desired. On the other hand, when the monofilament is of a fiber length of beyond 50 mm, it is broken into a plurality of pieces having a short fiber length upon the previous incorporation into the resin of the nonfoamed material layer, wherein the fluidization of the resin in such undesirable state as above described is not effectively prevented.

30 In addition, when a monofilament having a long fiber length is contained in a resin for the formation of the nonfoamed material layer, the resin containing the monofilament therein becomes to have an increased viscosity upon the formation of the nonfoamed material layer and because of this, it is necessary for the formation of the nonfoamed material layer to be conducted at a high temperature. In this case, there entails a problem in that the foaming agent and crosslinking agent contained in the resin for the formation of the nonfoamed material layer are decomposed.

35 In the present invention, it is important to make such that the resin constituting the nonfoamed material layer is readily impregnated in the fiber. For this purpose, the fiber is desired to have a diameter of 1 to 250  $\mu\text{m}$ . When a fiber having a diameter exceeding 250  $\mu\text{m}$  is contained in the resin constituting the nonfoamed material layer, there entail problems in that the fiber prevents the resin from desirably moving when foaming is cased in the nonfoamed material layer by virtue of the gas generated from the foaming agent, wherein there cannot be attained a high expansion ratio  
40 for the nonfoamed material layer. On the other hand, when a fiber having a diameter of less than 1  $\mu\text{m}$  is contained in the resin constituting the nonfoamed material layer, there entail problems in that the fiber is broken by the movement of the resin when foaming is cased in the nonfoamed material layer by virtue of the gas generated from the foaming agent, wherein the fluidization of the resin in such undesirable state as above described is not effectively prevented.

The fiber diameter is more preferably in the range of 3 to 50  $\mu\text{m}$ . In the case where the fiber is of a diameter of less  
45 than 3  $\mu\text{m}$ , the fiber is likely difficult to efficiently handle particularly in the layer lamination process. In the case where the fiber is of a diameter of beyond 5  $\mu\text{m}$ , the expansion ratio of the nonfoamed material layer is slightly reduced.

The fiber usable in the present invention can include fiber members of various configurations. Specific examples are monofilaments, woven fabrics, and nonwoven fabrics.

In the case of using a monofilament as the fiber, it is desired to be incorporated into the resin constituting the nonfoamed layer as above described. As for the amount of the monofilament to be added, it is preferably in the range of 0.5  
50 to 20 parts by weight versus 100 parts by weight of the resin of the nonfoamed material layer. When the amount of the monofilament to be added is less than 0.5 part by weight, the fluidization of the resin of the nonfoamed material layer in such undesirable state as above described is not effectively prevented. On the other hand, when the amount of the monofilament to be added is beyond 20 parts by weight, there entail problems in that the resin containing the monofilament in such large amount for the formation of the nonfoamed material layer becomes to have an excessively  
55 increased viscosity upon the formation of the nonfoamed material layer, wherein there entail problems in that the foaming agent and crosslinking agent contained in the resin for the formation of the nonfoamed material layer are decomposed; and the fluidization of the resin of the nonfoamed material layer in the process of forming a foamed material layer from the nonfoamed material layer is excessively prevented, wherein there cannot be attained the formation of a

foamed material layer with a high expansion ratio.

The formation of the nonfoamed material layer may be conducted, for example, in the following manner. That is, when a polyethylene series resin is used as the resin for the formation of the nonfoamed material layer, a composition comprising said resin, a given foaming agent and a given crosslinking agent is first provided, and a given monofilament is admixed into said composition, followed by subjecting to kneading at a temperature of 80 to 120 °C, whereby obtaining a sheet usable as the nonfoamed material layer.

In any case, since the foaming agent used in the present invention is decomposed at a temperature of 120 to 170 °C, the formation of the nonfoamed material layer is necessary to be conducted at a temperature which is lower than this decomposition temperature of the foaming agent.

In a preferred embodiment, as the fiber, either a woven fabric or a nonwoven fabric is used. These fabrics are configured such that respective constituent fibers are fixed with each other or these are controlled such that they are hardly mobilized. In the thermocompression treatment, the constituent resin of the foamed material layer is impregnated into such woven or nonwoven fabric, for instance, by laminating the latter to the former. In this case, since the woven or nonwoven fabric has such immobilized configuration as above described, the resin impregnated therein is in an immobilized state and because of this, no cavity is occurred upon subjecting the nonfoamed material layer to foaming.

Description will be made of the woven fabric and the nonwoven fabric.

The woven fabric is one produced by way of plain weave including thirl plain weave, twill weave, Turkey weave, mock leno weave, or leno weave.

In the present invention, woven fabrics which are produced by way of thirl plain weave are desirably used in order to attain desirable impregnation of the constituent resin of the nonfoamed material layer into the fiber.

The woven fabric has such a configuration that fibers are knitted so that their movements are minimized. Because of this, the woven fabric is effective in immobilizing the constituent resin of the nonfoamed material layer. In the case of using a woven fabric having a rough weave texture, it is desired to conduct filling treatment therefor by using an appropriate filler so that the weave texture is not broken.

As the filler used in the filling treatment, it is desired to use a filler which excels in adhesion with the constituent resin of the nonfoamed material layer and is not fused at the temperature employed in the thermocompression treatment.

As for the woven fabric, a binder is usually used for binding filaments. Such binder is desired to remove by way of heat treatment. By removing the binder in this way, the binding of the filaments is loosen so that the constituent resin of the nonfoamed material layer is readily impregnated into the woven fabric.

The nonwoven fabric is one produced by randomly or uniformly dispersing fibers and molding the fibers thus dispersed into a plain-like state using a binder. The binder used in this case is desired to have a heat resistance which is similar to that of the fibers. In addition, the binder is desired to excel in adhesion with the constituent resin of the nonfoamed material layer.

As for the length of the fiber used in the nonwoven fabric, when the mobility of the fiber is prevented by the binder, it is possible to use a fiber having a short length.

The nonwoven fabric usable in the present invention can include organic fiber nonwoven fabrics produced by way of leno weave without using a binder or by way of fiber welding without using a binder. In the case of using such organic fiber nonwoven fabric, a due care should be made so that the constituent fibers thereof are not separated one from the other during the thermocompression treatment.

Now, in the nonwoven fabric, the constituent fibers are not knitted each other but they are contacted with each other by means of the binder so as to immobilize them. This makes the resin impregnated in the nonwoven fabric such that it is difficult to mobilize.

As for the thickness of either the woven fabric or the nonwoven fabric used in the present invention, it is preferably in the range of 10 to 500  $\mu\text{m}$ . When the thickness is beyond 500  $\mu\text{m}$ , there entail problems in that the constituent resin of the nonfoamed material layer is not sufficiently impregnated in the woven or nonwoven fabric and because of this, there cannot be attained a sufficient adhesion with the resulting foamed material layer, wherein the foamed material layer is often separated from the woven or nonwoven fabric. On the other hand, when the thickness is less than 10  $\mu\text{m}$ , there entail problems in that there cannot be attained a sufficient thickness for preventing the constituent resin of the nonfoamed material layer from being undesirably fluidized, wherein there is a tendency that a recession is occurred at the surface of the resulting foamed material layer or/and a cavity is occurred within the foamed material layer.

The thickness of either the woven fabric or the nonwoven fabric is more preferably in the range of 50 to 200  $\mu\text{m}$ . In the case where the thickness is less than 50  $\mu\text{m}$ , there is a tendency that either the woven fabric or the nonwoven fabric is not readily handled upon the lamination thereof. In the case where the thickness is beyond 200  $\mu\text{m}$ , the expansion ratio of the nonfoamed material layer is slightly reduced.

As for each of the woven fabric and the nonwoven fabric used in the present invention, it is desired to be of an appropriate rough texture in terms of rate of hole area. Particularly, either the woven fabric or the nonwoven fabric is desired to have a rate of hole area in the range of 20 to 90%. In the case where the rate of hole area is less than 20%, there entail problems in that the constituent resin of the nonfoamed material layer is not desirably impregnated into the

fabric, wherein the effect of preventing the constituent resin of the nonfoamed material layer from being undesirably fluidized is small. In the case where the rate of hole area is beyond 90%, the constituent resin of the nonfoamed material layer cannot be sufficiently prevented from being undesirably fluidized.

In the present invention, each of the woven fabric and the nonwoven fabric is desired to satisfy all the above described factors, i.e., the foregoing diameter, length, thickness, and rate of hole area. As the characteristic including these factors, there can be used a weighing capacity. Particularly, each of the woven fabric and the nonwoven fabric is desired to have a weighing capacity in the range of 5 g/m<sup>2</sup> to 100 g/m<sup>2</sup>. In the case where the weighing capacity is less than 5 g/m<sup>2</sup>, the constituent resin of the nonfoamed material layer cannot be sufficiently prevented from being undesirably fluidized. In the case where the weighing capacity is beyond 100 g/m<sup>2</sup>, the amount of the constituent resin of the nonfoamed material layer remained without being fluidized is increased to cause a reduction in the expansion ratio of the nonfoamed material layer. In a more preferred embodiment, the weighing capacity is in the range of 10 g/m<sup>2</sup> to 50 g/m<sup>2</sup>. In this case, the amount of the constituent resin of the nonfoamed material layer remained without being fluidized is appropriate and a sufficient expansion ratio can be attained for the nonfoamed material layer.

In the present invention, in order to foam the nonfoamed material layer at a high expansion ratio, it is necessary to prevent the gas, which is generated by decomposing the foaming agent contained in the nonfoamed material layer, from leaking to the outside. In order to attain this purpose, the foregoing lower adhesive layer 102C (see, FIGs. 2(A) and 2(B)) disposed between the nonfoamed material layer and the insulating material layer also functions to seal so that the gas does not leak to the outside while functioning to ensure the adhesion between the two layers.

In order to foam the nonfoamed material layer at a high expansion ratio, the heat treatment of the nonfoamed material layer is desired to conduct at a high temperature within a short period of time. In order to seal the gas generated in the heat treatment of the nonfoamed material layer at a high temperature, the member engaged in sealing the gas is necessary to have a sufficient heat resistance. To seal the gas is desired to be conducted by way of edge sealing. The edge sealing may be conducted by using a release member as a lamination instrument, an adhesive as the above adhesive layer and an insulating member as the above insulating material layer. Particularly, when the adhesive layer situated under the insulating material layer (see, FIGs. 2(A) and 2(B)) is heated, it is fused to contact with the release member thereby preventing the gas from leaking to the outside.

When the adhesive layer has a low viscosity at a high temperature, the gas is liable to pass through the adhesive layer. Hence, the adhesive layer is required to have a sufficient heat resistance. For this purpose, the adhesive layer is desired to be crosslinked. The adhesive layer having been crosslinked has an improved cohesive force with respect to the constituent resin thereof and is free of the occurrence of a breakage in the layer.

As previously described, the adhesive layer functions to cause a covalent bond not only at the interface with the foamed material layer but also at the interface with the insulating material layer, whereby the adhesion between the insulating material layer and the foamed material layer is ensured.

Now, the insulating material layer 103 (see, FIGs. 1(A) and 1(B) and FIGs. 2(A) and 2(B)) has a function of ensuring the adhesion between the photovoltaic element and the foamed material layer and another function of surely electrically isolating the photovoltaic element from the outside. The insulating material layer is required to excel in electrical insulation, physical strength, moisture resistance, and heat resistance. In the case where the insulating material layer is insufficient in the adhesion with the photovoltaic element or the foamed material layer, it is possible to dispose an adhesive layer (corresponding to the upper adhesive layer 102D (see, FIG. 2(B)) between the insulating material layer and the photovoltaic element or an adhesive layer (corresponding to the lower adhesive layer 102C (see, FIGs. 2(B)) between the insulating material layer and the foamed material layer. In this case, in view of work efficiency, it is desired to use a laminate comprising the lower adhesive layer, the insulating material layer, and the upper adhesive layer laminated in the named order. Each of these adhesive layers is desired to compose a resin which can be fused at a high temperature and can be crosslinked at a high temperature. However, in the case of a solar cell module which is used under environmental condition where the temperature of the module is raised up to about 80 °C, the crosslinking of the resin is not always necessary.

The insulating material layer may comprise a biaxially oriented polyethylene terephthalate film, a nylon film, a glass fiber member, or a nonwoven fabric member of a plastic fiber.

The photovoltaic element 104 may comprises an appropriate photovoltaic element used in single crystal silicon solar cells, polycrystalline silicon solar cells, amorphous silicon solar cells, copper-indium-selenide solar cells, or compound semiconductor solar cells.

Herein, as an example of such photovoltaic element, description will be made of a photovoltaic element having a structure comprising a semiconductor photoactive layer as a photoelectric conversion member and a transparent and conductive layer disposed in the named order on an electrically conductive substrate.

FIG. 3 is a schematic cross-sectional view illustrating the constitution of such photovoltaic element.

In FIG. 3, reference numeral 201 indicates an electrically conductive substrate, reference numeral 202 a back reflecting layer, reference numeral 203 a semiconductor active layer, reference numeral 204 a transparent and conductive layer, reference numeral 205 a collecting electrode (or a grid electrode), reference numeral 206a a power outputting terminal on the positive side, reference numeral 206b a power outputting terminal on the negative side, reference



numeral 207 an electrical connection means, and reference numeral 208 an insulator.

The photovoltaic element shown in FIG. 3 comprises the back reflecting layer 202, the semiconductor photoactive layer 203, the transparent and conductive layer 204, and the collecting electrode 205 disposed in the named order on the electrically conductive substrate 201, wherein the outputting terminal 206a is electrically connected to the collecting electrode 205 by means of the electrical connection means 207 and it is extending from the collecting electrode while being insulated by means of an insulator 208, and the outputting terminal 206b is electrically connected to the electrically conductive substrate 201 by means of an electrical connection means (not shown). In this configuration, the positive side power outputting terminal and the negative side power outputting terminal may be changed into a negative side power outputting terminal and a positive side power outputting terminal depending upon the constitution of the semiconductor photoactive layer.

The electrically conductive substrate 201 serves not only as a substrate for the photovoltaic element but also as a lower electrode. As for the electrically conductive substrate 201, there is no particular restriction as long as it has an electrically conductive surface. Specifically, it may be an electrically conductive member composed of a metal such as Si, Ta, Mo, W, Al, Cu, Ti, or Fe, or an electrically conductive member composed of an alloy of these metals such as stainless steel, or the like. Besides these, the electrically conductive substrate 201 may comprise a carbon sheet or a Pb-plated steel sheet. Alternatively, the electrically conductive substrate 201 may be a film or sheet made of a synthetic resin or a sheet made of a ceramic. In this case, the substrate is deposited with an electrically conductive film on the surface thereof.

The back reflecting layer 202 disposed on the electrically conductive substrate 201 may comprise a metal layer, a metal oxide layer, or a two-layered structure comprising a metal layer and a metal oxide layer. The metal layer may be composed of a metal such as Ti, Cr, Mo, W, Al, Ag, or Ni, or an alloy of these metals. The metal oxide layer may comprise a metal oxide such as ZnO, TiO<sub>2</sub>, SnO<sub>2</sub>, or the like.

The back reflecting layer 202 is desired to have a roughened surface in order to make incident light to be effectively utilized.

The back reflecting layer 202 may be properly formed by a conventional film-forming technique such as resistant heating evaporation, electron beam evaporation, or sputtering.

The semiconductor photoactive layer 203 functions to conduct photoelectric conversion. The semiconductor photoactive layer may be composed of a non-single crystal silicon semiconductor material such as an amorphous silicon semiconductor material or polycrystalline silicon semiconductor material, or a compound semiconductor material. In any case, the semiconductor photoactive layer comprised of any of these semiconductor materials may be of a stacked structure with a pin junction, a pn junction or a shottky type junction. Specific examples of the compound semiconductor material are CuInSe<sub>2</sub>, CuInS<sub>2</sub>, GaAs, CdS/Cu<sub>2</sub>S, CdS/CdTe, CdS/InP, CdTe/Cu<sub>2</sub>Te, and the like.

The semiconductor photoactive layer 203 comprised of any of the above mentioned semiconductor materials may be properly formed by a conventional film-forming technique. For instance, the non-single crystal silicon semiconductor photoactive layer may be formed by a conventional chemical vapor phase growing technique such as plasma CVD or light-induced CVD using proper film-forming raw material gas capable of imparting silicon atoms such as silane gas or a conventional physical vapor phase growing technique such as sputtering using a Si-target. The semiconductor photoactive layer composed of a polycrystalline silicon semiconductor material may be formed by a conventional polycrystalline silicon film-forming manner of providing a fused silicon material and subjecting the fused silicon material to film-making processing or another conventional polycrystalline silicon film-forming manner of subjecting an amorphous silicon material to heat treatment.

The semiconductor photoactive layer 203 composed of any of the above mentioned compound semiconductor materials may be properly formed by a conventional ion plating, ion beam deposition, vacuum evaporation, sputtering, or electrolytic technique in which a precipitate is caused by way of electrolysis of a desired electrolyte.

The transparent and conductive layer 204 functions as an upper electrode. The transparent and conductive layer may comprise In<sub>2</sub>O<sub>3</sub>, SnO<sub>2</sub>, In<sub>2</sub>O<sub>3</sub>-SnO<sub>2</sub> (ITO), ZnO, TiO<sub>2</sub>, or Cd<sub>2</sub>SnO<sub>4</sub>. Besides these, it may comprise a crystalline semiconductor layer doped with an appropriate impurity with a high concentration.

The transparent and conductive layer 204 constituted by any of the above mentioned materials may be properly formed by a conventional resistant heating evaporation, electron beam evaporation, sputtering, spraying, or CVD.

The above described impurity-doped crystalline semiconductor layer as the transparent and conductive layer 204 may be properly formed by a conventional impurity-diffusion film-forming method.

For the purpose of effectively collecting an electric current generated by virtue of a photoelectromotive force, the collecting electrode (or the grid electrode) 205 may be disposed on the transparent and conductive layer 204. The collecting electrode 205 may be in the form of a a stripe shape or comb shape.

The collecting electrode 205 may comprise a metal such as Ti, Cr, Mo, W, Al, Ag, Ni, Cu, or Sn, or an alloy of these metals. Alternatively, the collecting electrode 205 may be formed of an electrically conductive paste or an electrically conductive resin. The electrically conductive paste can include electrically conductive pastes comprising powdery Ag, Au, Cu, Ni, or carbon dispersed in an appropriate binder resin. The binder resin herein can include polyester, epoxy resin, acrylic resin, alkyd resin, polyvinyl acetate, rubber, urethane resin, and phenol resin.



The collecting electrode 205 may be properly formed by means of sputtering using a mask pattern, resistant heating evaporation, or CVD. It may be also properly formed by a manner of depositing a metal film over the entire surface and subjecting the metal film to etching treatment to form a desired pattern, a manner of directly forming a grid electrode pattern by means of light-induced CVD, or a manner of forming a negative pattern corresponding to a grid electrode pattern and subjecting the resultant to plating treatment.

The formation of the collecting electrode 205 using any of the above described electrically conductive pastes may be conducted in a manner of subjecting the electrically conductive paste to screen printing or a manner of fixing a metal wire to the screen-printed electrically conductive paste, if necessary, using a solder.

The outputting terminals 206a and 206b serve to output an electromotive force. The outputting terminal 206a is electrically connected to the collecting electrode 205 by means of the electrical connection means 207. The electrical connection means 207 may comprise an electrically conductive layer formed by using a metal body and an electrically conductive paste or a solder. The outputting terminal 206b is electrically connected to the electrically conductive substrate by means of the electrical connection means (not shown). The electrical connection means herein may comprise an electrical connection region formed by spot welding or soldering an appropriate metal body such as copper tab.

In general, there are provided a plurality of photovoltaic elements having the above constitution, and they are integrated in series connection or in parallel connection depending upon a desired voltage or electric current. It is possible to dispose the integrated body on an insulating member such that a desired voltage or electric current can be obtained.

Description will be made of the surface side covering material 105 (see, FIGs. 1(A) and 1(B), and FIGs. 2(A) and 2(B)) used in the present invention.

The surface side covering material 105 is required to have functions of covering the irregularities at the light receiving face of the photovoltaic element while preventing the photovoltaic element from being influenced by external factors such as temperature changes and/or humidity changes in the external environment, externally applied impacts, or the like, and allowing a sufficient quantity of light to pass therethrough to arrive at the photovoltaic element so that the photovoltaic element continuously performs photoelectric conversion. Hence, the surface side covering material is required to excel in transparency, weatherability, adhesion, packing property, heat resistance, and impact resistance. In order for the surface side covering material to meet these requirements, the surface side covering material is desired to comprise a laminate comprising a filler layer (or an adhesive layer) and a surface protective film.

Description will be made of the filler layer in the following.

The filler layer is required to comprise a resin excelling especially in transparency, weatherability, and adhesion. And the filler layer is required to exhibit a flowability of filling the irregularities at the photovoltaic element in the process of producing a solar cell module. In the case where the production of the solar cell module is conducted by way of thermocompression treatment, the filler layer comprises a thermoplastic resin such as polyolefinic resin, butyral resin, urethane resin, silicone resin, or fluororesin. Specific examples are EVA (ethylene-vinyl acetate copolymer), EMA (ethylene-methyl acrylate copolymer), EEA (ethylene-ethyl acrylate copolymer), and polyvinyl butyral resin.

In the case where the filler layer is insufficient in terms of adhesion, it is possible for the filler layer to have an improved adhesion by incorporating a silane coupling agent or a titanate coupling agent into the resin constituting the filler layer.

The filler layer essentially comprised of the above described resin excels in weatherability. However, in order to attain a further improved weatherability for the filler layer, the filler layer is desired to contain an appropriate UV absorber such as organic UV absorber or inorganic absorber. The organic UV absorber can include organic compounds such as salicylic acid series compounds, benzophenone series compounds, benzotriazole series compounds, and acrylonitrile series compounds. Specific examples are 2-hydroxy-4-methoxybenzophenone, 2-hydroxy-4-n-octoxybenzophenone, and 2-(2-hydroxy-5-t-octylphenyl)benzotriazole.

Specific examples of the inorganic UV absorber are  $\text{TiO}_2$ ,  $\text{CeO}_2$ ,  $\text{ZnO}$ , and  $\text{SnO}_2$ .

Further, in order to improve the resistance to photo-induced degradation of the filler layer, the filler layer may contain an appropriate photo stabilizer in addition to the above described UV absorber.

Further in addition, in order to attain a further improved heat resistance and thermally processing property for the resin as the filler layer, the resin as the filler layer may contain an appropriate antioxidant.

In order for the filler layer to have an improved physical strength, it is possible to incorporate an appropriate additive such as glass single fiber or glass bead into the resin as the filler layer. Alternatively, it is also possible to use a glass fiber nonwoven fabric or an organic fiber nonwoven fabric upon the lamination of the filler layer.

Description will be made of the surface protective film in the following.

The surface protective film is positioned at the outermost surface of the solar cell module and because of this, it is required to excel in transparency, weatherability, water repellency, heat resistance, pollution resistance, and physical strength. As for the water repellency, it is preferably  $50^\circ$  or more or more preferably  $70^\circ$  or more in terms of contact angle against water. Therefore, the surface protective film is comprised of a highly transparent resin such as fluororesin and silicone resin. Of these, the fluororesin is the most appropriate. Specific examples of the fluororesin are ethylene-tetrafluoroethylene copolymer (ETFE), poly(chlorotrifluoroethylene) resin (PCTFE), tetrafluoroethylene-perfluoroalkyl-

vinylether copolymer (PFA), tetrafluoroethylene-hexafluoropropylene copolymer (FEP), vinylidene fluoride, and vinyl fluoride resin.

In order to attain a further improvement in the adhesion of the surface protective film with the filler layer, a surface of the surface protective film to be contacted with the filler layer is desired to be subjected to surface treatment. The surface treatment can include corona discharging treatment, plasma treatment, ozone treatment, and primer coating. Of these, the corona discharging treatment is the most appropriate because there can be attained the purpose at a high speed while using a relatively simple apparatus.

In the following, description will be made of a process for the production of a solar cell module according to the present invention using the foregoing photovoltaic element, surface side covering material, and back side covering material. In the present invention, the production of the solar cell is desired to be conducted by way of vacuum lamination. In order to ensure the formation of a skin layer, it is desired to enclose the photovoltaic element by way of face-up lamination. The face-up lamination herein means a lamination manner of enclosing the photovoltaic element while upward facing its light receiving face. On the other hand, a lamination manner of enclosing the photovoltaic element while downward facing its light receiving face is called face-down lamination.

Now, the gas generated from the foaming agent when the nonfoamed layer is foamed moves in the upward direction and because of this, the amount of the resin on the rear side of the photovoltaic element is increased to readily cause the formation of the skin layer.

Particularly, in the face-up lamination, on a metal plate made of, for instance, aluminum which is provided with an O-ring, there is laid a release member, then the foregoing back side covering material, the foregoing photovoltaic element, and the foregoing surface side covering material are stacked in the named order on the release member to form a stacked body, and a rubber sheet having a good releasing property is superposed over the stacked body to seal the stacked body between the metal plate and the rubber sheet while using the O-ring (the resultant herein will be hereinafter referred to as air back system). Thereafter, the space of the air back system containing the stacked body between the metal plate and the rubber sheet is vacuumed at a predetermined vacuum degree by means of a vacuum pump. Then, under reduced pressure, the stacked body thus vacuum-treated in the air back system is introduced into an oven maintained at a temperature of, for instance, 80 to 200 °C which is suitable for bonding the surface side covering material and the back side covering material to the photovoltaic element so that the photovoltaic element is covered by the surface side covering material and the back side covering material, wherein the stacked body is subjected to heat treatment for a predetermined period of time. And still under reduced pressure, the stacked body is cooled. By this, there is obtained a solar cell module.

In the present invention, it is desired to conduct the foregoing edge sealing in order to prevent the gas, which is generated from the foaming agent when the nonfoamed material layer is foamed, from leaking to the outside.

In the production process according to the present invention, such air back system as above described is employed in the thermocompression treatment. In the manner of using such air back system, as apparent from the above description, the back side covering material, photovoltaic element and surface side covering material are stacked to obtain a stacked body, the resultant stacked body is vacuumed to release the air present therein, and the vacuum-treated stacked body is heated while being compressed through the air back system. However, in the above thermocompression treatment, the nonfoamed material layer is foamed into a foamed material due to the gas generated from the foaming agent contained in the nonfoamed material layer and because of this, it is necessary to remain the gas generated from the foaming agent during the thermocompression treatment in order to efficiently foam the nonfoamed material layer. For this purpose, as previously described, to employ the edge sealing is effective.

In the above, it is necessary to prevent the gas from leaking to the outside through the release member. For this purpose, it is desired for the release member to have a nitrogen permeability of  $1.0 \times 10^4 \text{ cm}^3/(\text{m}^2 \cdot 24 \text{ h} \cdot \text{atm})$  or less and a heat resistance such that the release member is not melted at the temperature employed in the thermocompression treatment in order to maintain an edge seal resulted.

Such release member can include metallic members having a releasing property and a melting point of more than 150 °C and which satisfies the above conditions.

In the present invention, in order to attain a substantially smooth surface for the resulting solar cell module, it is possible to use a rigid plate. That is, when the vacuum lamination (that is, the thermocompression treatment) is conducted by way of the face-up manner, the foregoing rubber sheet follows the irregularities at the light receiving surface of the photovoltaic element to make the resulting solar cell module to have irregularities on the surface thereof. Further, in the case where the photovoltaic element is flexible, the back side covering material follows the irregularities based on the wiring or by-pass diode at the rear face of the photovoltaic element to deform the resulting solar cell module. In order to prevent the occurrence of these problems, it is desired to dispose said rigid plate on the surface of the surface side covering material. Specifically, the rigid plate is disposed on the foregoing stacked body comprising the back side covering material, photovoltaic element and surface side covering material stacked in the named order on the release member.

In the present invention, it is possible to conduct embossing for the surface of the stacked body. The embossing may be conducted by a manner of introducing the stacked body into an oven or a manner of heating the stacked body using a metal plate provided with a heater therein. As for the conditions relating to heating speed and maximum tem-

perature in the embossing should be properly determined depending on the crosslinking ability of the resin used in the surface side covering material and back side covering material and the viscosity of the resin when fused.

Further, in the present invention, the decomposition temperature of the foaming agent contained in the nonfoamed material layer is greatly related to the conditions relating to heating speed and maximum temperature in the embossing.

5 In the following, description will be made of the edge sealing process in order to efficiently foaming the nonfoamed material layer in the vacuum lamination, using a vacuum laminator of a single vacuum chamber system shown FIGs. 4(A) and 4(B).

First, on an aluminum plate 701 provided with an O-ring 702, a release member 703 as a constituent of the laminator is laid. On the release member 703, there are stacked a nonfoamed material layer 704, a composite 705 comprising a lower adhesive layer, an insulating material layer and an upper adhesive layer, a photovoltaic element 706 and a surface side covering material 707 in the named order to form a stacked body. (The stacked body herein may have a support member on its rear side). Then, a silicone rubber sheet as a flexible member 708 is superposed over the stacked body on the aluminum plate 701 while hermetically sealing between the aluminum plate 701 and the flexible member 708 by means of the O-ring 702 (see, FIG. 7(A)). In this case, each of the release member 703 and the composite 705 (and also the support member (not shown in the figures) in the case where it is provided) is necessary to be greater than the nonfoamed material layer 704 in terms of the size as shown in FIG. 4(A).

Thereafter, in a first step, the inside of the space containing the stacked body between the flexible member 708 and the aluminum plate 701 is exhausted to a predetermined vacuum degree by means of a vacuum pump (not shown), whereby the flexible member 708 is sagged toward the aluminum plate 701 side to thereby compress the stacked body, wherein the composite 705 is contacted with the release member 703 such that the nonfoamed material layer 704 is enclosed between the release member 703 and the composite 705 as shown in FIG. 4(B).

Then, in a second step, an electric heater (not shown) installed in the aluminum plate 701 is energized to heat the stacked body to a predetermined temperature, wherein the foaming agent contained in the nonfoamed material layer 704 is decomposed to generate gas whereby causing foaming in the nonfoamed material layer 704. In this case, the gas generated is efficiently utilized in foaming the nonfoamed material layer 704 without leaking to the outside because the nonfoamed material layer 704 is desirably enclosed by the release member 703 and the composite 705. By this, the nonfoamed material layer 704 is effectively converted into a foamed material layer. Thus, there is obtained a solar cell module according to the present invention. By the way, when the size of each of the release member 703 and the composite 705 is made to be the same as that of the nonfoamed material layer 704, there can be attained the formation of a practically acceptable foamed material layer. But the expansion ratio in this case is inferior to that in the above edge sealing case.

In the following, detailed embodiments of a solar cell module in which a material comprising a foamed material and a fiber is used in the present invention with reference to examples which are not intended to restrict the scope of the present invention.

#### Example 1

In this example, there was prepared a solar cell module having the configuration shown in FIG. 5 which comprises a stacked body comprising a fiber member 401, a nonfoamed material layer 402 (which will be eventually converted into a foamed material layer), a lower adhesive layer 403, an insulating material layer 404, an upper adhesive layer 405, a solar cell 406 (or a photovoltaic element), a reinforcing member 407, a filler layer 408 (comprising an adhesive material), and a surface protective layer 409 laminated in the named order.

The solar cell module having the configuration shown in FIG. 5 was prepared in the following manner.

1. As the fiber member 401, there was provided a nonwoven polypropylene fiber member.
2. As the nonfoamed material layer 402, there was provided a nonfoamed material sheet prepared in the following manner.

That is, 100 parts by weight of an ethylene-vinyl acetate resin (vinyl acetate content: 15 wt.%, melt flow rate: 9 dg/min.), 40 parts by weight of a precipitated calcium carbonate (primary particle size: about 3  $\mu$ m) as a nucleus material, 5 parts by weight of a mixture composed of azodicarbonamide and dinitrosopentamethylenetetramine as a foaming agent, 1 part by weight of dicumylperoxide as a crosslinking agent, 0.5 part by weight of stearic acid, and 0.1 part by weight of carbon black as a pigment were well mixed, followed by subjecting to sheet forming treatment using a reverse L-letter type four-roll calender, to thereby obtain a nonfoamed material sheet having a thickness of 1.0 mm used as the nonfoamed material layer 402.

3. As each of the lower adhesive layer 403, the upper adhesive layer 405, and the filler layer 408, there was provided a resin sheet prepared in the following manner.

That is, 100 parts by weight of an ethylene-vinyl acetate resin (vinyl acetate content: 33 wt.%, melt flow rate: 30 dg/min.), 1.5 parts by weight of 2,5-dimethyl-2,5-bis(t-butylperoxy)hexane as a crosslinking agent, 0.3 part by weight of 2-hydroxy-4-n-octoxybenzophenone as an UV absorber, 0.2 part by weight of tris(mono-nonylphenoxy)phosphine oxide as a thermal stabilizer, and 0.1 part by weight of carbon black as a pigment were well mixed, followed by subjecting to sheet forming treatment using a reverse L-letter type four-roll calender, to thereby obtain a resin sheet having a thickness of 0.1 mm used as the lower adhesive layer 403, the upper adhesive layer 405, and the filler layer 408.

nyl)phosphate as an antioxidant, and 0.1 part by weight of (2,2,6,6-tetramethyl-4-piperidyl)sebacate as a photo stabilizer were well mixed to obtain a composition. The composition thus obtained was subjected to T-die extrusion, to thereby obtain a 460  $\mu\text{m}$  thick resin sheet.

In this way, there were obtained three resin sheets having a thickness of 460  $\mu\text{m}$  used as the lower adhesive layer 403, the upper adhesive layer 405, and the filler layer 408.

Particularly, as for the resin sheet used as the lower adhesive layer 403, it was made to have a size which is greater as much as 20 cm than that of the nonfoamed material layer 402 in terms of the length of each edge.

And, as for the resin sheet used as the filler layer 408, its surface to be contacted with the reinforcing member 407 was subjected to corona discharge treatment.

4. As the insulating material layer 404, there was provided a 50  $\mu\text{m}$  thick biaxially oriented polyethylene terephthalate (PET) film having opposite surfaces applied with corona discharge treatment and having a size which is greater as much as 20 cm than that of the nonfoamed material layer 402 in terms of the length of each edge.

5. As the solar cell 406, there was provided a solar cell prepared in the following manner.

That is, there was prepared a solar cell having the configuration shown in FIGs. 6(A), 6(B) and 7 which comprises a plurality of photovoltaic elements integrated in series connection. Herein, FIG. 6(A) is a schematic plan view of the solar cell, FIG. 6(B) is a schematic cross-sectional view, taken along the line A-A in FIG. 6(A), and FIG. 7 is a schematic view illustrating the backface of the solar cell.

There was firstly provided a well-cleaned stainless steel plate as a substrate 301. On the substrate 301, there was formed a two-layered back reflecting layer 302 comprising a 5000  $\text{\AA}$  thick Al film and a 5000  $\text{\AA}$  thick ZnO film by means of the conventional sputtering process, followed by forming, on the back reflecting layer 302, a tandem type a-Si photoelectric conversion semiconductor layer 303 with a nip/nip structure comprising a 150  $\text{\AA}$  thick n-type layer/a 4000  $\text{\AA}$  thick i-type layer/a 100  $\text{\AA}$  thick p-type layer/a 100  $\text{\AA}$  thick n-type layer/a 800  $\text{\AA}$  thick i-type layer/a 100  $\text{\AA}$  thick p-type layer being laminated in the named order from the substrate side by means of the conventional plasma CVD manner, wherein an n-type a-Si film as each n-type layer was formed from a mixture of  $\text{SiH}_4$  gas,  $\text{PH}_3$  gas and  $\text{H}_2$  gas; an i-type a-Si film as each i-type layer was formed from a mixture of  $\text{SiH}_4$  gas and  $\text{H}_2$  gas; and a p-type  $\mu\text{c-Si}$  film as each p-type layer was formed from a mixture of  $\text{SiH}_4$  gas,  $\text{BF}_3$  gas and  $\text{H}_2$  gas. Then, on the semiconductor layer 303, there was formed a 700  $\text{\AA}$  thick  $\text{In}_2\text{O}_3$  film as a transparent conductive layer 304 by means of the conventional heat resistance evaporation process wherein an In-source was evaporated in an  $\text{O}_2$  atmosphere. The resultant was cut into a plurality of elements having a size of 30 cm x 9 cm. From the plurality of elements obtained, 13 elements were randomly selected.

As for each of these 13 elements, a plurality of collecting grid electrodes 305 were formed by screen-printing an Ag-paste (merchandise No. 5007, produced by Du Pont Company) on the transparent conductive layer 304. The grid electrodes 305 thus formed on the transparent conductive layer 304 were connected in series by bonding a wire bus bar 306 (comprising a solder-plated copper wire of 400  $\mu\text{m}$  in diameter) to the grid electrodes 305 using an Ag-paste 307 (merchandise No. 220, produced by Amicon Company). As for the resultant, a copper tub 308 having a thickness of 100  $\mu\text{m}$  was fixed to the substrate 301 by means of spot welding. Thus, there were obtained 13 photovoltaic elements.

The resultant 13 photovoltaic elements were integrated in series connection by connecting the copper tub 308 of one of the photovoltaic element with the wire bus bar 306 of the other photovoltaic element using a solder. Then, on the rear face of each photovoltaic element, a by-pass diode 309 of 2.5 mm in diameter was fixed using an insulating tape 315 of 140  $\mu\text{m}$  in thickness (comprising a 100  $\mu\text{m}$  thick polyethylene terephthalate film having a 40  $\mu\text{m}$  thick adhesive layer formed thereon), and the by-pass diode 309 was connected to a positive terminal and a negative terminal of the photovoltaic element using a solder. And the same insulating tape was bonded over the by-pass diode. Thereafter, to the photovoltaic element situated on one end side, a negative power outputting copper tub 310 of 100  $\mu\text{m}$  in thickness was fixed using a double-coated tape of 65  $\mu\text{m}$  in thickness, and a positive power outputting copper tub 311 of 100  $\mu\text{m}$  in thickness was fixed to the photovoltaic element situated on the other end side using an insulating tape 312 of 140  $\mu\text{m}$  in thickness (comprising a 100  $\mu\text{m}$  thick polyethylene terephthalate film having a 40  $\mu\text{m}$  thick adhesive layer formed thereon). To the negative power outputting copper tub 310, the copper tub 308 of the photovoltaic element having the negative power outputting copper tub 310 fixed thereto was connected using a solder. To the positive power outputting copper tub 311, the wire bus bar 306 of the photovoltaic element having the positive power outputting copper tub 311 fixed thereto was connected by turning up said wire bus bar and fixing it to the positive power outputting copper tub using a solder.

In order to attain a one end power outputting system, the negative power outputting copper tub 310 was extended by soldering a copper tub 313 thereto to establish a projected negative power outputting terminal, and the copper tub 313 was bonded onto all the photovoltaic elements using an insulating tape 314 of 140  $\mu\text{m}$  in thickness (comprising a 100  $\mu\text{m}$  thick polyethylene terephthalate film having a 40  $\mu\text{m}$  thick adhesive layer formed thereon). As for the positive power outputting copper tub 311, it was establish a projected positive power outputting terminal in the same manner.

Thus, there was obtained a solar cell used as the solar cell 406.

6. As the reinforcing member 407, there was provided a nonwoven glass fiber member (linear diameter: 10  $\mu\text{m}$ , weighing: 80  $\text{g/m}^2$ ).

7. As the surface protective layer 409, there was provided a 50  $\mu\text{m}$  thick nonoriented ethylene-tetrafluoroethylene copolymer (ETFE) film.

8. Preparation of a solar cell module:

On a surface of an aluminum plate of 10 mm in thickness, a composite comprising a steel member having an ETFE film of 200  $\mu\text{m}$  in thickness laminated thereon as a release member was laid. Then, on the aluminum plate having the release member laid thereon, there were stacked the nonwoven polypropylene fiber member as the fiber member 401, the nonfoamed material sheet as the nonfoamed material layer 402, the resin sheet as the lower adhesive layer 403, the PET film as the insulating material layer 404, the resin sheet as the upper adhesive layer 405, the solar cell as the solar cell 406, the nonwoven glass fiber member as the reinforcing member 407, the resin sheet as the filler layer 408, and the ETFE film as the surface protective layer 409 in the named order to form a stacked body. Successively, there were superposed a steel plate of 0.8 mm in thickness was superposed and a heat resistant silicone rubber sheet of 3 mm in thickness in the named order on the stacked body so as to enclose the stacked body. And the space containing the stacked body between the aluminum plate and the steel plate having the silicone rubber sheet superposed thereon was sealed using an O-ring (the body established herein will be referred to as lamination instrument). Then, using a vacuum pump, said space containing the stacked body was vacuumed so that the inside of the stacked body became 10 mmHg. After the inside of the stacked body was sufficiently vacuumed, the lamination instrument was introduced into a direct drying equipment maintained at 180 °C and it was maintained for 65 minutes, under condition of continuing the vacuuming operation. Thereafter, while still continuing the vacuuming operation, the lamination instrument was taken out from the drying equipment, followed by cooling to room temperature.

Thereafter, the inside pressure of the lamination instrument was returned to atmospheric pressure to obtain a vacuum-treated stacked body as a solar cell module. The nonfoamed material layer 402 was found that it had been converted into a foamed layer having a thickness of 5.0 mm.

The above procedures were repeated to obtain a plurality of solar cell modules.

#### Evaluation

Using the resultant solar cell modules, evaluation was conducted with respect to initial exterior appearance, endurance against changes in environmental temperature and humidity, and cushioning property.

The evaluated results obtained are shown in Table 1.

The evaluation of each of the above evaluation items was conducted in the following manner.

#### (1) Evaluation of the initial exterior appearance:

The solar cell module was optically observed. The observed result is shown in Table 1 based on the following criteria:

- ◎ : a case wherein none of peeling of the surface side covering material, residual air bubble therein, recession at the foamed material layer, and protrusion at the foamed material layer generated due to the irregularities present at the rear face of the solar cell is observed;
- : a case wherein a practically negligible small protrusion at the foamed material layer generated due to the irregularities present at the rear face of the solar cell is observed; and
- X : a case wherein defects such as distinguishable layer separation in the surface side covering material, residual air bubble, recessions in the foamed material layer, and protrusions in the foamed material layer generated due to the irregularities present at the rear face of the solar cell are observed.

#### (2) Evaluation of the endurance against changes in environmental temperature and humidity:

The solar cell module was subjected to alternate repetition of a cycle of exposing to an atmosphere of - 40 °C for an hour and a cycle of exposing to an atmosphere of 85 °C/85 %RH for four hours 200 times, and thereafter, its exterior appearance was optically observed. The observed result is shown in Table 1 based on the following criteria:

- ◎ : a case where no change is observed in the exterior appearance;
- : a case where a slight change is observed in the exterior appearance but it is not problematic in practice, slight internal layer separation is recognized by way of finger touch, or slight internal separation is observed for the first time when the solar cell module is destructured; and

X : a case where practically problematic peeling is observed at the exterior.

(3) Evaluation of the cushioning property:

5 Considering the situation that the solar cell module is placed on a sandy place and somebody steps thereon, the solar cell module was subjected to load test in the following manner. That is, sands having a maximum particle size of about 3 mm and an average particle size of 1 mm were laid on the ground, the solar cell module was placed thereon, and a weight of 60 Kg having a size of 10 cm x 10 cm was put on the solar cell module, followed by allowing to stand for 10 minutes. Thereafter, the exterior appearance of the solar cell module was optically observed. Then, the solar cell  
10 module was subjected to high-voltage dielectric breakdown test in the following manner. That is, as for the solar cell module having subjected to the above load test, the positive electrode and the negative electrode were short-circuited, followed by immersing in a solution containing 0.1 wt.% of a surface active agent TORITON X-100 (trademark name, produced by Rhom & Haars Company) and having an electrically conductivity of more than 3500 ohm.cm, wherein the portion of the solar cell module to which the above load was applied was immersed in the solution without immersing  
15 its power outputting terminals therein. And a negative electrode from a power source is fixed to the solution side and a positive electrode from said power source was fixed to the power outputting terminal. Thereafter, the power source was switched on to supply a voltage of 2000 V, wherein a leakage current was examined.

The evaluated results obtained are shown in Table 1 based on the following criteria:

- 20 ◎ : a case wherein neither change in the exterior appearance nor deformation in the covering material are observed, and the leakage current is less than 0.5  $\mu$ A;  
○ : a case wherein a slight change in the exterior and a slight deformation in the covering material are observed but they are not problematic in practice, and the leakage current is less than 0.5  $\mu$ A; and  
X : a case wherein an apparent change in the exterior and an apparent deformation in the covering material  
25 are observed, and the leakage current is beyond 0.5  $\mu$ A.

Example 2

The procedures of Example 1 were repeated, except that the nonfoamed material sheet was replaced by a non-  
30 foamed material sheet having a thickness of 1.5 mm prepared in accordance with the procedures for the preparation of the nonfoamed material layer in Example 1 except for using no crosslinking agent, to thereby obtain a plurality of solar cell modules. The foamed material layer resulted was found to have a thickness of 4.5 mm.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are shown in Table 1.

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Example 3

The procedures of Example 1 were repeated, except that the crosslinking agent contained in the resin sheet as the lower adhesive layer 403 was excluded, to thereby obtain a plurality of solar cell modules. The foamed material layer  
40 resulted was found to have a thickness of 4.4 mm.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are shown in Table 1.

Example 4

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The procedures of Example 1 were repeated, except that the fiber member 401 was not used and the nonfoamed material sheet used as the nonfoamed material layer 402 was replaced by a nonfoamed material sheet containing a fiber which was prepared in a manner as will be described below, to thereby obtain a plurality of solar cell modules.

The above fiber-containing nonfoamed material sheet was prepared in the following manner. That is, 100 parts by  
50 weight of an ethylene-vinyl acetate resin (vinyl acetate content: 15 wt.%, melt flow rate: 9 dg/min.), 15 parts by weight of a glass fiber (length: 25 mm, linear diameter: 10  $\mu$ m), 40 parts by weight of a precipitated calcium carbonate (primary particle size: about 3  $\mu$ m) as a nucleus material, 5 parts by weight of a mixture composed of azodicarbonamide and dinitrosopentamethylenetetramine as a foaming agent, 1 part by weight of dicumylperoxide as a crosslinking agent, 0.5  
55 part by weight of stearic acid, and 0.1 part by weight of carbon black as a pigment were well mixed, followed by subjecting to sheet forming treatment using a reverse L-letter type four-roll calender, to thereby obtain a nonfoamed material sheet having a thickness of 1.0 mm used as the nonfoamed material layer 402.

The foamed material layer resulted was found to have a thickness of 4.2 mm.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are shown in Table 1.

## Reference Example 1

In this reference example, there was prepared a solar cell module having the configuration shown in FIG. 8 which comprises a stacked body comprising a foamed material layer 501, a lower adhesive layer 502, an insulating material layer 503, an upper adhesive layer 504, a solar cell 505 (or a photovoltaic element), a reinforcing member 506, a filler layer 507 (comprising an adhesive material), and a surface protective layer 508 laminated in the named order.

First, in the same manner as Example 1, there were provided a biaxially oriented PET film used as the insulating material layer 503, a resin sheet used as the upper adhesive layer 504, a solar cell used as the solar cell 505, a nonwoven glass fiber member as the reinforcing member 506, a resin sheet as the filler layer 507, and a nonoriented ETFE film used as the the surface protective layer 508.

Separately, there was provided a foamed polyethylene sheet used as the foamed material layer 501. And for the formation of the lower adhesive layer 502, there was prepared a resin composition in accordance with the manner employed in the preparation of the resin sheet in Example 1.

Then, on a surface of an aluminum plate of 20 mm in thickness which is provided with a heater therein, there are laminated the PET film as the insulating material layer 503, the resin sheet as the upper adhesive layer 504, the solar cell as the solar cell 505, the nonwoven glass fiber member as the reinforcing member 506, the resin sheet as the filler layer 507, and the ETFE film as the surface protective layer 508 in the named order to form a stacked body.

Successively, there was superposed a heat resistant silicone rubber sheet of 3 mm in thickness on the stacked body so as to enclose the stacked body. And the space containing the stacked body between the aluminum plate and the silicon rubber sheet was sealed using an O-ring. Then, using a vacuum pump, said space containing the stacked body was vacuumed so that the inside of the stacked body became 10 mmHg. After the inside of the stacked body was sufficiently vacuumed, by energizing the heater of the aluminum plate, the stacked body was heated to 150 °C and it was maintained at this temperature for 20 minutes under condition of continuing the vacuuming operation. Thereafter, while still continuing the vacuuming operation, the stacked body was cooled to room temperature. Thereafter, the inside pressure of the above described space was returned to atmospheric pressure to obtain a vacuum-treated stacked body.

Then, the foregoing composition for the formation of the lower adhesive layer 502 was applied on the PET film as the insulating material layer 503 of the resultant stacked body by means of the conventional roll coating process, followed by drying for 10 minutes, to thereby form a layer as the lower adhesive layer 502. On the lower adhesive layer 502 thus formed, the foregoing foamed polyethylene sheet was laminated to form a layer as the foamed material layer 501. By this, there was obtained a solar cell module.

The above procedures were repeated to obtain a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are shown in Table 1.

## Reference Example 2

The procedures of Example 1 were repeated, except that the nonfoamed material sheet was replaced by a 5 mm thick nonfoamed chloroprene rubber sheet and the expansion ratio of the chloroprene rubber sheet was changed, to thereby obtain a plurality of solar cell modules. The foamed material layer resulted was found to have a thickness of 4.5 mm.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are shown in Table 1.

## Reference Example 3

The procedures of Example 1 were repeated, except that the nonwoven polypropylene fiber member as the fiber member 401 was not used, to thereby obtain a plurality of solar cell modules. The foamed material layer resulted was found to have a thickness of 5.0 mm.

Any of the resultant solar cell modules was found to have recessions at portions of the foamed material layer situated in the vicinity of the by-pass diodes of the solar cell. Therefore, any of the resultant solar cell modules was found to be apparently inferior in initial exterior appearance. This result is shown in Table 1.

As for the solar cell modules obtained in this reference example, no evaluation was conducted as for any of the evaluation items described in Example 1.

## Reference Example 4

The procedures of Reference Example 1 were repeated, except that neither the foamed material layer nor the lower adhesive layer were formed, to thereby obtain a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are shown in Table 1.

Table 1

	initial exterior appearance	endurance against changes in environmental temperature and humidity	cushioning property
Example 1	⊙	⊙	⊙
Example 2	⊙	⊙	○
Example 3	⊙	⊙	○
Example 4	⊙	⊙	○
Reference Example 1	○	X	⊙
Reference Example 2	○	X	⊙
Reference Example 3	X	not evaluated	not evaluated
Reference Example 4	⊙	○	X

As apparent from the results shown in Table 1, it is understood that any of the solar cell modules obtained in the above examples 1 to 4 having a specific foamed material layer such that the irregularities present at the rear face of the solar cell are filled is free of the occurrence of layer separation even when it is repeatedly used under severe environmental conditions with high temperature and high humidity or low temperature or with frequent changes in temperature and humidity, and in addition, it excels in portability and flexibility, and it is hardly damaged even when it is placed on an irregular surface of sandy plain, sandy beach, or the like and somebody steps thereon.

#### Example 5

In this example, there was prepared a solar cell module having the configuration shown in FIG. 9 which comprises a stacked body comprising a base member 601, a nonfoamed material layer 602 (which will be eventually converted into a foamed material layer), an insulating material layer 603, a solar cell 604 (or a photovoltaic element), a reinforcing member 605, a filler layer 606 (comprising an adhesive material), and a surface protective layer 607 laminated in the named order.

A solar cell module having the configuration shown in FIG. 9 was prepared in the following manner.

1. As the base member 601, there was provided a Zn-plated steel plate having a thickness of 300  $\mu\text{m}$ .
2. As the nonfoamed material layer 602, there was provided a nonfoamed material sheet having a thickness of 1.5 mm prepared in accordance with the procedures for the preparation of the nonfoamed material sheet in Example 1.
3. As the insulating material layer 603, there was provided a 50  $\mu\text{m}$  thick biaxially oriented polyethylene terephthalate (PET) film having opposite surfaces applied with corona discharge treatment and having a size which is greater as much as 5 cm than that of the nonfoamed material layer 602 in terms of the length of each edge.
4. As the solar cell 604, there was provided a solar cell prepared in accordance with the procedures for the preparation of the solar cell in Example 1.
5. As the reinforcing member 605, there was provided a nonwoven glass fiber member (linear diameter: 10  $\mu\text{m}$ , weighing: 80  $\text{g}/\text{m}^2$ ).
6. As the filler layer 606, there was provided a 460  $\mu\text{m}$  thick resin sheet which was prepared in the following manner.  
That is, 100 parts by weight of an ethylene-vinyl acetate resin (vinyl acetate content: 33 wt.%, melt flow rate: 30  $\text{dg}/\text{min}$ ), 1.5 parts by weight of 2,5-dimethyl-2,5-bis(t-butylperoxy)hexane as a crosslinking agent, 0.3 part by weight of 2-hydroxy-4-n-octoxybenzophenone as an UV absorber, 0.2 part by weight of tris(mono-nonylphenyl)phosphate as an antioxidant, and 0.1 part by weight of (2,2,6,6-tetramethyl-4-piperidyl)sebacate as a photo stabilizer were well mixed to obtain a composition. The composition thus obtained was subjected to T-die extrusion, to thereby obtain a 460  $\mu\text{m}$  thick resin sheet.
7. As the surface protective layer 607, there was provided a 50  $\mu\text{m}$  thick nonoriented ethylene-tetrafluoroethylene copolymer (ETFE) film having a surface applied with corona discharge treatment which is to be contacted with the filler layer 606.
8. Preparation of a solar cell module:

On a surface of an aluminum plate of 10 mm in thickness, an ETFE film of 200  $\mu\text{m}$  in thickness as a pollution preventive member was laid. Then, on the aluminum plate having the ETFE film laid thereon, there were stacked the Zn-plated steel plate as the base member 601, the nonfoamed material sheet as the nonfoamed material layer



602, a resin sheet (prepared in accordance with the above described procedures of forming the resin sheet used as the filler layer 606), the PET film as the insulating material layer 603, the solar cell as the solar cell 604, the non-woven glass fiber member as the reinforcing member 605, the resin sheet as the filler layer 606, and the ETFE film as the surface protective layer 607 in the named order to form a stacked body.

5

Successively, there was superposed a heat resistant silicone rubber sheet of 3 mm in thickness on the stacked body so as to enclose the stacked body. And the space containing the stacked body between the aluminum plate and the silicone rubber sheet was sealed using an O-ring (the body established herein will be referred to as lamination instrument). Then, using a vacuum pump, said space containing the stacked body was vacuumed so that the inside of the stacked body became 10 mmHg. After the inside of the stacked body was sufficiently vacuumed, the lamination instrument was introduced into a direct drying equipment maintained at 120 °C and it was maintained for 100 minutes, under condition of continuing the vacuuming operation. Thereafter, while still continuing the vacuuming operation, the lamination instrument was taken out from the drying equipment, followed by cooling to room temperature. Thereafter, the inside pressure of the lamination instrument was returned to atmospheric pressure to obtain a vacuum-treated stacked body as a solar cell module. The nonfoamed material layer 602 was found that it had been converted into a foamed layer having a thickness of 5.0 mm.

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The above procedures were repeated to obtain a plurality of solar cell modules.

#### Evaluation

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Using the resultant solar cell modules, evaluation was conducted with respect to (i) endurance against changes in environmental temperature and humidity, (ii) cushioning property, and (iii) rate of change in initial photoelectric conversion efficiency after exposure to light.

The evaluated results obtained are shown in Table 2.

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The evaluation of each of the above evaluation items was conducted in the following manner.

#### (1) Evaluation of the endurance against changes in environmental temperature and humidity:

The evaluation of this evaluation item was conducted in the same manner as in Example 1.

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The evaluated result obtained is shown in Table 1 based on the same criteria as in Example 1.

#### (2) Evaluation of the cushioning property:

The evaluation of this evaluation item was conducted in the same manner as in Example 1.

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The evaluated result obtained is shown in Table 1 based on the same criteria as in Example 1

#### (3) Evaluation of the change of rate in initial photoelectric conversion efficiency:

First, as for the solar cell module, its initial photoelectric conversion efficiency was measured. Then, the solar cell module was continuously irradiated with pseudo sunlight of 1.5 AM to deteriorate until the photoelectric conversion efficiency became substantially constant at a given value. Thereafter, its photoelectric conversion efficiency was measured. The measured result is shown in Table 2 in a value relative to the initial photoelectric conversion efficiency, which is set at 1.

#### Example 6

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The procedures of Example 5 were repeated, except that the Zn-plated steel plate as the base member 601 was replaced by a 150  $\mu$ m thick low-density polyethylene (LDPE) film containing 10 wt.% of titanium oxide and 0.2 wt.% of carbon black, to thereby obtain a plurality of solar cell modules. The foamed material layer resulted was found to have a thickness of 3.8 mm.

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Using the resultant solar cell modules, evaluation was conducted with respect to (i) endurance against changes in environmental temperature and humidity, (ii) cushioning property, and (iii) rate of change in initial photoelectric conversion efficiency after exposure to light. The evaluation of each of the evaluation items (i) and (ii) was conducted in the manner as in Example 1. The evaluation of the evaluation of the evaluation item (iii) was conducted in the same manner as in Example 5.

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The evaluated results obtained are shown in Table 2.

## Example 7

The procedures of Example 5 were repeated, except that the base member was not used, to thereby obtain a plurality of solar cell modules. The foamed material layer resulted was found to have a thickness of 3.6 mm.

Using the resultant solar cell modules, evaluation was conducted with respect to (i) endurance against changes in environmental temperature and humidity, (ii) cushioning property, and (iii) rate of change in initial photoelectric conversion efficiency after exposure to light.

The evaluation of each of the evaluation items (i) and (ii) was conducted in the manner as in Example 1. The evaluation of the evaluation of the evaluation item (iii) was conducted in the same manner as in Example 5.

The evaluated results obtained are shown in Table 2.

## Example 8

The procedures of Example 5 were repeated, except that the nonfoamed material sheet as the nonfoamed material layer 602 was replaced by two nonfoamed material sheets of 1.5 mm in thickness obtained by repeating the procedures for the formation of the nonfoamed material sheet in Example 5 except for using no crosslinking agent, to thereby obtain a plurality of solar cell modules. The foamed material layer resulted was found to have a thickness of 4.2 mm.

Using the resultant solar cell modules, evaluation was conducted with respect to (i) endurance against changes in environmental temperature and humidity, and (ii) rate of change in initial photoelectric conversion efficiency after exposure to light.

The evaluation of the evaluation items (i) was conducted in the manner as in Example 1. The evaluation of the evaluation of the evaluation item (ii) was conducted in the same manner as in Example 5.

The evaluated results obtained are shown in Table 2.

## Example 9

The procedures of Example 6 were repeated, except that the Zn-plated steel plate as the base member 601, the nonfoamed material sheet as the nonfoamed material layer 602, and the PET film as the insulating material layer 603 were made to be of the same size in terms of the length of the corresponding edge, to thereby obtain a plurality of solar cell modules. The foamed material layer resulted was found to have a thickness of 3.4 mm.

Using the resultant solar cell modules, evaluation was conducted with respect to (i) endurance against changes in environmental temperature and humidity, (ii) cushioning property, and (iii) rate of change in initial photoelectric conversion efficiency after exposure to light.

The evaluation of each of the evaluation items (i) and (ii) was conducted in the manner as in Example 1. The evaluation of the evaluation of the evaluation item (iii) was conducted in the same manner as in Example 5.

The evaluated results obtained are shown in Table 2.

## Example 10

The procedures of Example 5 were repeated, except that the thermocompression bonding of the stacked body was conducted using an apparatus capable of conducting thermocompression treatment under atmospheric pressure condition and which is provided with a press cylinder provided with a flexible sheet comprising a silicone rubber wherein the stacked body was subjected to thermocompression treatment at 150 °C under pressure condition of 1 Kg/cm<sup>2</sup> for 20 minutes, to thereby obtain a plurality of solar cell modules. The foamed material layer resulted was found to have a thickness of 2.8 mm.

Using the resultant solar cell modules, evaluation was conducted with respect to (i) endurance against changes in environmental temperature and humidity, and (ii) rate of change in initial photoelectric conversion efficiency after exposure to light.

The evaluation of the evaluation items (i) was conducted in the manner as in Example 1. The evaluation of the evaluation of the evaluation item (ii) was conducted in the same manner as in Example 5.

The evaluated results obtained are shown in Table 2.

## Reference Example 5

In this reference example, there was prepared a solar cell module having the configuration shown in FIG. 10 which comprises a stacked body comprising a foamed material layer 801, an adhesive layer 802, a lower reinforcing member 803, an insulating material layer 804, a solar cell 805 (or a photovoltaic element), an upper reinforcing member 806, a filler layer 807 (comprising an adhesive material), and a surface protective layer 808 laminated in the named order.

A solar cell module having the configuration shown in FIG. 10 was prepared in the following manner.

1. As the foamed material layer 801, there was provided a foamed polystyrene sheet having a thickness of 5 mm.
2. As the adhesive layer 802, there was provided an acrylic emulsion adhesive.
3. As the lower reinforcing member 803, there was provided a Zn-plated steel plate having a thickness of 300  $\mu\text{m}$ .
4. As the insulating material layer 804, there was provided a 50  $\mu\text{m}$  thick biaxially oriented polyethylene terephthalate (PET) film having opposite surfaces applied with corona discharge treatment.
5. As the solar cell 805, there was provided a solar cell prepared in accordance with the procedures for the preparation of the solar cell in Example 1.
6. As the upper reinforcing member 806, there was provided a nonwoven glass fiber member (linear diameter: 10  $\mu\text{m}$ , weighing: 80  $\text{g}/\text{m}^2$ ).
7. As the filler layer 807, there was provided a 460  $\mu\text{m}$  thick resin sheet prepared in accordance with the procedures for the preparation of the resin sheet used as the filler layer in Example 5.
8. As the surface protective layer 808, there was provided a 50  $\mu\text{m}$  thick nonoriented ethylene-tetrafluoroethylene copolymer (ETFE) film having a surface applied with corona discharge treatment which is to be contacted with the filler layer 807.
9. Preparation of a solar cell module:

On a surface of an aluminum plate of 10 mm in thickness which is provided with a heater, there were stacked the Zn-plated steel plate as the lower reinforcing member 803, the PET film as the insulating material layer 804, the solar cell as the solar cell 805, the nonwoven glass fiber member as the upper reinforcing member 806, the resin sheet as the filler layer 807, and the ETFE film as the surface protective layer 808 in the named order to form a stacked body.

Successively, there was superposed a heat resistant silicone rubber sheet of 3 mm in thickness on the stacked body so as to enclose the stacked body. And the space containing the stacked body between the aluminum plate and the silicone rubber sheet was sealed using an O-ring. Then, using a vacuum pump, said space containing the stacked body was vacuumed so that the inside of the stacked body became 10 mmHg. After the inside of the stacked body was sufficiently vacuumed, by energizing the heater of the aluminum plate, the stacked body was heated to 150  $^{\circ}\text{C}$  and it was maintained at this temperature for 20 minutes under condition of continuing the vacuuming operation. Thereafter, while still continuing the vacuuming operation, the stacked body was cooled to room temperature. Thereafter, the inside pressure of the above described space was returned to atmospheric pressure to obtain a vacuum-treated stacked body.

Then, the foregoing acrylic emulsion adhesive was applied on the Zn-plated steel plate as the lower reinforcing member 803 of the stacked body by means of the conventional roll coating process, followed by drying for 10 minutes, to thereby form a layer as the adhesive layer 802. Successively, on the adhesive layer 802 thus formed, the foregoing foamed polystyrene sheet was laminated to form a layer as the foamed material layer 801. By this, there was obtained a solar cell module.

The above procedures were repeated to obtain a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted with respect to (i) endurance against changes in environmental temperature and humidity, and (ii) rate of change in initial photoelectric conversion efficiency after exposure to light.

The evaluation of the evaluation items (i) was conducted in the manner as in Example 1. The evaluation of the evaluation item (ii) was conducted in the same manner as in Example 5.

The evaluated results obtained are shown in Table 2.

#### Reference Example 6

In this reference example, there was prepared a solar cell module having the configuration shown in FIG. 11 which comprises a stacked body comprising a foamed material layer 901, an adhesive layer 902, an insulating material layer 903, a solar cell 904 (or a photovoltaic element), a reinforcing member 905, a filler layer 906 (comprising an adhesive material), and a surface protective layer 907 laminated in the named order.

A solar cell module having the configuration shown in FIG. 11 was prepared in the following manner.

1. As the foamed material layer 901, there was provided a foamed polyethylene sheet having a thickness of 4 mm.
2. As the adhesive layer 902, there was provided an acrylic emulsion adhesive.
3. As the insulating material layer 903, there was provided a 50  $\mu\text{m}$  thick biaxially oriented polyethylene terephthalate (PET) film having opposite surfaces applied with corona discharge treatment.
4. As the solar cell 904, there was provided a solar cell prepared in accordance with the procedures for the preparation of the solar cell in Example 1.
5. As the reinforcing member 905, there was provided a nonwoven glass fiber member (linear diameter: 10  $\mu\text{m}$ , weighing: 80  $\text{g}/\text{m}^2$ ).
6. As the filler layer 906, there was provided a 460  $\mu\text{m}$  thick resin sheet prepared in accordance with the procedures

for the preparation of the resin sheet used as the filler layer in Example 5.

7. As the surface protective layer 907, there was provided a 50  $\mu\text{m}$  thick nonoriented ethylene-tetrafluoroethylene copolymer (ETFE) film having a surface applied with corona discharge treatment which is to be contacted with the filler layer 906.

8. Preparation of a solar cell module:

On a surface of an aluminum plate of 10 mm in thickness which is provided with a heater, there were stacked the PET film as the insulating material layer 903, the solar cell as the solar cell 904, the nonwoven glass fiber member as the reinforcing member 905, the resin sheet as the filler layer 906, and the ETFE film as the surface protective layer 907 in the named order to form a stacked body.

Successively, there was superposed a heat resistant silicone rubber sheet of 3 mm in thickness on the stacked body so as to enclose the stacked body. And the space containing the stacked body between the aluminum plate and the silicone rubber sheet was sealed using an O-ring. Then, using a vacuum pump, said space containing the stacked body was vacuumed so that the inside of the stacked body became 10 mmHg. After the inside of the stacked body was sufficiently vacuumed, by energizing the heater of the aluminum plate, the stacked body was heated to 150  $^{\circ}\text{C}$  and it was maintained at this temperature for 20 minutes under condition of continuing the vacuuming operation. Thereafter, while still continuing the vacuuming operation, the stacked body was cooled to room temperature. Thereafter, the inside pressure of the above described space was returned to atmospheric pressure to obtain a vacuum-treated stacked body.

Then, the foregoing acrylic emulsion adhesive was applied on the PET film as the insulating material layer 903 of the stacked body by means of the conventional roll coating process, followed by drying for 10 minutes, to thereby form a layer as the adhesive layer 902. Successively, on the adhesive layer 902 thus formed, the foregoing foamed polyethylene sheet was laminated to form a layer as the foamed material layer 901. By this, there was obtained a solar cell module.

The above procedures were repeated to obtain a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted with respect to (i) endurance against changes in environmental temperature and humidity, (ii) cushioning property, and (iii) rate of change in initial photoelectric conversion efficiency after exposure to light.

The evaluation of each of the evaluation items (i) and (ii) was conducted in the manner as in Example 1. The evaluation of the evaluation of the evaluation item (iii) was conducted in the same manner as in Example 5.

The evaluated results obtained are shown in Table 2.

#### Reference Example 7

The procedures of Reference Example 6 were repeated, except that the foamed polyethylene sheet used as the foamed material layer before the lamination thereof to the adhesive layer was treated by subjecting to alternate repetition of a cycle of exposing to an atmosphere of 80  $^{\circ}\text{C}$  for four hours and a cycle of exposing to an atmosphere of -40  $^{\circ}\text{C}$  for an hour 10 times, to thereby obtain a plurality of solar cell modules.

The foamed polyethylene sheet treated as described above was found to have a thickness of 4 mm which is the same as that of the starting foamed polyethylene sheet.

Using the resultant solar cell modules, evaluation was conducted with respect to (i) endurance against changes in environmental temperature and humidity, (ii) cushioning property, and (iii) rate of change in initial photoelectric conversion efficiency after exposure to light.

The evaluation of each of the evaluation items (i) and (ii) was conducted in the manner as in Example 1. The evaluation of the evaluation of the evaluation item (iii) was conducted in the same manner as in Example 5.

The evaluated results obtained are shown in Table 2.

#### Reference Example 8

The procedures of Reference Example 5 were repeated, except that neither the foamed material layer nor the adhesive layer were used, to thereby obtain a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted with respect to (i) endurance against changes in environmental temperature and humidity, and (ii) rate of change in initial photoelectric conversion efficiency after exposure to light.

The evaluation of the evaluation items (i) was conducted in the manner as in Example 1. The evaluation of the evaluation of the evaluation item (ii) was conducted in the same manner as in Example 5.

The evaluated results obtained are shown in Table 2.

## Reference Example 9

The procedures of Reference Example 6 were repeated, except that neither the foamed material layer nor the adhesive layer were used, to thereby obtain a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted with respect to (i) endurance against changes in environmental temperature and humidity, (ii) cushioning property, and (iii) rate of change in initial photoelectric conversion efficiency after exposure to light.

The evaluation of each of the evaluation items (i) and (ii) was conducted in the manner as in Example 1. The evaluation of the evaluation of the evaluation item (iii) was conducted in the same manner as in Example 5.

The evaluated results obtained are shown in Table 2.

Table 2

	endurance against changes in environmental temperature and humidity	cushioning property	change of rate in initial photoelectric conversion efficiency
Example 5	⊙	not evaluated	89
Example 6	⊙	⊙	89
Example 7	⊙	⊙	89
Example 8	⊙	not evaluated	88
Example 9	⊙	⊙	88
Example 10	⊙	not evaluated	87
Reference Example 5	X	not evaluated	84
Reference Example 6	X	○	86
Reference Example 7	X	○	86
Reference Example 8	○	not evaluated	80
Reference Example 9	○	X	80

As apparent from the results shown in Table 2, the following facts are understood. That is, any of the solar cell modules obtained in the above examples 5 to 10 (belonging to the present invention) having a specific foamed material layer in which the irregularities present at the rear face of the solar cell are filled is free of the occurrence of layer separation even when it is repeatedly used under severe environmental conditions with high temperature and high humidity or low temperature or with frequent changes in temperature and humidity, and in addition, it excels in portability and flexibility, and it is hardly damaged even when it is placed on an irregular surface of sandy plain, sandy beach, or the like and weighty somebody steps thereon. Further, because any of the solar cell modules belonging to the present invention has the specific foamed material layer of exhibiting an excellent adiathermic performance, it excels in endurance against high temperature and is slight in light deterioration and therefore, it always stably exhibits a satisfactory photoelectric conversion efficiency even when it is permanently placed outdoor. Further in addition, because the formation of the foamed layer is conducted by way of foaming a given nonfoamed material during the thermocompression treatment of a given stacked body having said nonfoamed material therein, the production of a solar cell module can be accomplished for a reduced period of time, and therefore, the production cost of a solar cell module can be diminished.

Now, it is considered that a solar cell module having such back side covering material provided with the specific foamed material layer might have an occasion for the foamed material layer to be deformed due to the occurrence of its heat contraction or the like because of changes in environmental temperature. In order to prevent the occurrence of this problem, it is desired for the back side covering material of the solar cell module to be designed such that it is hardly deformed wherever the solar cell module is used.

In the following, description will be made about this with reference to FIG. 12.

FIG. 12 is a schematic cross-sectional view illustrating the constitution of an example of a solar cell module according to the present invention. In FIG. 12, reference numeral 122 indicates a photovoltaic element, reference numeral 123 a surface side covering material disposed to cover a light receiving face of the photovoltaic element 122, and reference numeral 121 a back side covering material disposed to cover the rear face of the photovoltaic element 122.

In the present invention, it is desired for the back side covering material 121 to be designed such that it deforms at

a deformation proportion of 5 to 75% in terms of the layer thickness when a load of  $2 \text{ Kg/cm}^2$  is applied thereon at room temperature. The deformation proportion herein will be hereinafter referred to as layer thickness deformation proportion.

When the layer thickness deformation proportion is less than 5%, the deformation of the back side converging material is excessively small and because of this, the back side covering material is incapable of sufficiently following the irregularities and the like present at the rear face of the photovoltaic element, wherein when somebody steps on the solar cell module, there is a tendency that the external pressure caused at this time is convergently applied to the recessions of the irregularities to entail a problem in that the back side covering material is damaged or the photovoltaic element is damaged. On the other hand, when the layer thickness deformation proportion is beyond 75%, the back side covering material excessively follow the irregularities and the like present at the rear face of the photovoltaic element to entail problems in that portions of the back side covering material situated in the recessions of the irregularities are undesirably thinned such that the back side covering material does not exhibit a sufficient protective ability and because of this, there is occurred a necessity of excessively thickening the back side covering material in order for the back side covering material to exhibit a sufficient protective performance.

As for the back side covering material 121, as previously described, it may comprise a single layer or a stacked structure comprising a plurality of layers. Particularly, in the case of a solar cell module having a photovoltaic element provided with an electrically conductive substrate, when the back side covering material is disposed to cover the rear face side of the photovoltaic element by way of deformation of the back side covering material, it is desired for the back side covering material to be designed such that it comprises a stacked structure comprising, for example, an adhesive layer and a protective resin layer laminated in the named order from the photovoltaic element side in order for the back side covering material to exhibit a function of sufficiently electrically isolating the electrically conductive substrate of the photovoltaic element while attaining a sufficient adhesion between the back side covering material and the photovoltaic element.

The above protective resin layer principally serves to protect the photovoltaic element while being deformed. The protective resin layer corresponds the foregoing foamed material layer according to the present invention. In order for the protective resin layer to exhibit the above function of protecting the photovoltaic element by way of deformation, the protective resin layer may be composed of a resin which is low in hardness. Such resin can include ethylene-vinyl acetate copolymer, polyethylene, polypropylene, polyester, chloroprene, rubber sheets such as SBR rubber sheet, and extended (or foamed) materials of these.

In order to diminish the amount of a hard resin layer used and also in order to lighten a solar cell obtained, it is desired to use a foamed material layer, particularly, a foamed material layer having a glass transition temperature ( $T_g$ ) of  $-50$  to  $80^\circ\text{C}$  as the protective resin layer. In a preferred embodiment, the foamed material layer is composed of a material excelling in extension in order to attain a solar cell module having a sufficient flexibility.

As for the protective resin layer, it is desired to be treated so as to have a sufficient heat history in advance. For this purpose, the protective resin layer may be annealed by means of an heat energy of about  $150^\circ\text{C}$ . However, it is desired to make the protective resin layer to have a sufficient heat history by thermocompressing it to the photovoltaic element during the lamination process of producing a solar cell module. Further, in order for the protective resin layer to have a sufficient resistance to solvents, it is possible for the protective resin layer to have a film or sheet which is high in resistance to solvents.

As for the solar cell module shown in FIG. 12, the detailed constitution of the photovoltaic element and surface side covering material and the process of the solar cell module are as previously described.

In the following, detailed embodiments of a solar cell module configured such that it has a resistance against various external factors including external pressure, impacts, and the like in the present invention with reference to examples which are not intended to restrict the scope of the present invention.

#### Example 11

In this example, there was prepared a solar cell module having the configuration shown in FIG. 13 which comprises a stacked body comprising a backface side protective layer 131, a first adhesive layer 132, an insulating layer 133, a second adhesive layer 134, a photovoltaic element (a solar cell) 135, a reinforcing member 136, a third adhesive layer 137, and a surface protective layer 138 laminated in the named order.

A solar cell module having the configuration shown in FIG. 13 was prepared in the following manner.

1. As the backface side protective layer 131, there was provided a foamed chloroprene sheet having a thickness of 4 mm.
2. As the first and second adhesive layers 132 and 134, there were provided two EVA sheets having a thickness of  $300 \mu\text{m}$ .
3. As the insulating layer 133, there was provided a PET film having a thickness of  $100 \mu\text{m}$ .
4. As the solar cell 135, there was provided a solar cell having the configuration shown in FIG. 3 which was pre-

pared in the following manner.

That is, there was firstly provided a well-cleaned stainless steel plate as a substrate 201. On the substrate 201, there was formed a two-layered back reflecting layer 202 comprising a 5000 Å thick Al film and a 5000 Å thick ZnO film by means of the conventional sputtering process. On the back reflecting layer 202, there was formed a tandem type a-Si photoelectric conversion semiconductor layer 203 with a nip/nip structure comprising a 150 Å thick n-type layer/a 4000 Å thick i-type layer/a 100 Å thick p-type layer/a 100 Å thick n-type layer/a 800 Å thick i-type layer/a 100 Å thick p-type layer being laminated in the named order from the substrate side by means of the conventional plasma CVD manner, wherein an n-type a-Si film as each n-type layer was formed from a mixture of SiH<sub>4</sub> gas, PH<sub>3</sub> gas and H<sub>2</sub> gas; an i-type a-Si film as each i-type layer was formed from a mixture of SiH<sub>4</sub> gas and H<sub>2</sub> gas; and a p-type  $\mu$ c-Si film as each p-type layer was formed from a mixture of SiH<sub>4</sub> gas, BF<sub>3</sub> gas and H<sub>2</sub> gas. Then, on the semiconductor layer 203, there was formed a 700 Å thick In<sub>2</sub>O<sub>3</sub> film as a transparent conductive layer 204 by means of the conventional heat resistance evaporation process wherein an In-source was evaporated in an O<sub>2</sub> atmosphere. The resultant was cut into a plurality of elements having a size of 30 cm x 15 cm. From the plurality of elements obtained, two elements were randomly selected.

As for each of the two elements, an Ag-paste comprising powdered Ag dispersed in polyester resin (trademark name: Ag-paste No. 5007, produced by Du Pont Company) was screen-printed on the transparent conductive layer 204, followed by drying, to thereby form a grid electrode as the collecting electrode 205. By this, there were obtained two photovoltaic elements.

The resultant two photovoltaic elements were integrated in series connection using a copper tub of 50  $\mu$ m in thickness and an Ag-paste (merchandise No. 220, produced by Amicon Company). A copper tub of 50  $\mu$ m in thickness as the negative power outputting terminal 206 was fixed to the substrate 201 using an Ag-paste (merchandise No. 220, produced by Amicon Company). Then, a polyamide resin film having a thickness of 50  $\mu$ m (trademark name: CAPTON FILM, produced by Sumitomo 3M Kabushiki Kaisha) as the insulator 208 was disposed as shown in FIG. 3 and a copper tub of 50  $\mu$ m in thickness as the positive power outputting terminal 206a was fixed to the collecting electrode 205 using an Ag-paste (merchandise No. 220, produced by Amicon Company). Thus, there was obtained a solar cell.

5. As the reinforcing member 136, there was provided a nonwoven glass fiber member (linear diameter: 10  $\mu$ m, weighing: 80 g/m<sup>2</sup>).

6. As the third adhesive layer 137, there was provided an EVA sheet of 460  $\mu$ m in thickness.

7. As the surface protective layer 138, there was provided a fluororesin film of 50  $\mu$ m in thickness having a surface applied with corona discharge treatment which is to be contacted with the third adhesive layer 137.

8. Preparation of a solar cell module:

On a surface of an aluminum plate of 20 mm in thickness which is provided with a heater therein, there were stacked the foamed chloroprene sheet as the backface side protective layer 131, the EVA sheet as the first adhesive layer 132, the PET film as the insulating layer 133, the EVA sheet as the second adhesive layer 134, the solar cell 135, the nonwoven glass fiber member as the reinforcing member 136, the EVA sheet as the third adhesive layer 137, and the fluororesin film as the surface protective layer 138 in the named order to form a stacked body.

Successively, there was superposed a heat resistant silicone rubber sheet of 3 mm in thickness on the stacked body so as to enclose the stacked body. And the space containing the stacked body between the aluminum plate and the silicone rubber sheet was sealed using an O-ring. Then, using a vacuum pump, said space containing the stacked body was vacuumed so that the inside of the stacked body became 10 mmHg. After the inside of the stacked body was sufficiently vacuumed, by energizing the heater of the aluminum plate, the stacked body was heated to 150 °C and it was maintained at this temperature for 20 minutes under condition of continuing the vacuuming operation. Thereafter, while still continuing the vacuuming operation, the stacked body was cooled to room temperature. Thereafter, the inside pressure of the above described space was returned to atmospheric pressure to obtain a solar cell module.

The above procedures were repeated to obtain a plurality of solar cell modules.

#### Evaluation

Using the resultant solar cell modules, evaluation was conducted with respect to endurance against changes in environmental temperature, cushioning property, impact resistance, and adhesion in environment with a high temperature and humidity.

The evaluated results obtained are shown in Table 3.

The evaluation of each of the above evaluation items was conducted in the following manner.

#### (1) Evaluation of the endurance against changes in environmental temperature:

The solar cell module was subjected to alternate repetition of a cycle of exposing to an atmosphere of - 40 °C for

an hour and a cycle of exposing to an atmosphere of 85 °C for an hour 50 times, and thereafter, its exterior appearance was optically observed. The observed result is shown in Table 3 based on the following criteria:

- 5    ⓪ :        a case where no change is observed in the exterior appearance;  
      ○ :        a case where a slight change is observed in the exterior appearance but it is not problematic in practice;  
      X :        a case where practically problematic peeling, crack or coloring is observed at the exterior.

(2) Evaluation of the cushioning property:

- 10    The evaluation of this evaluation item was conducted in the same manner as in Example 1.  
      The evaluated result obtained is shown in Table 3 based on the same criteria as in Example 1.

(3) Evaluation of the impact resistance:

- 15    The solar cell module was subjected to hail impact test in order to examine the ability of the covering material to protect the inside of a solar cell module against external pressure and impacts. This test was conducted in the following manner. That is, ten balls of ice, each having a diameter of one inch, were made to collide with each portion of the solar cell module in which the physical strength is weak (the center of the solar cell, corners of the module, edges, connection portion of the solar cell) at a speed of 23.2 m/sec. The solar cell module thus treated was optically examined in terms  
 20 of the presence or absence of layer separation and cracking, and in terms of photoelectric conversion efficiency. The evaluation of the photoelectric conversion efficiency was conducted in a manner wherein the photoelectric conversion efficiencies before and after the hail impact test were measured, and the ratio of change therebetween was examined.  
      The results obtained are shown in Table 3 based on the following criteria:

- 25    ⓪ :        a case wherein layer separation and cracking are not observed at all, and the change ratio is less than 5%;  
      ○ :        a case wherein slight layer separation and cracking are observed but the change ratio is less than 5%; and  
      X :        a case wherein layer separation and cracking are frequently observed and the change ratio is 5% or above.

(4) Evaluation of the adhesion in environment with a high temperature and humidity:

- 30    The solar cell module was maintained in an atmosphere with 85 °C/85 %RH for 100 hours, and the solar cell module thus treated was subjected to T-peel test in an atmosphere with 85 °C/85 %RH to examine the layer adhesion of a given end portion of the covering material of the solar cell module.

The examined result obtained is shown in Table 3 based on the following criteria:

- 35    ⓪ :        a case wherein the layer adhesion is excellent;  
      ○ :        a case wherein the layer adhesion is satisfactory; and  
      X :        a case wherein the layer adhesion is insufficient.

40    Example 12

- The procedures of Example 11 were repeated, except that the backface side protective layer 131 was comprised of a foamed polyethylene sheet having a thickness of 2 mm, and the temperature of 150 °C and the period of time of 20 minutes in the thermocompression bonding process of the stacked body were changed respectively to 80 °C and 40  
 45 minutes, to thereby obtain a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 11.

The evaluated results obtained are shown in Table 3.

Example 13

- 50    The procedures of Example 11 were repeated, except that the backface side protective layer 131 was comprised of an urethane resin sheet having a thickness of 2 mm, to thereby obtain a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 11.

The evaluated results obtained are shown in Table 3.

55    Example 14

A solar cell module having the configuration shown in FIG. 13 was prepared in the following manner.



1. As the backface side protective layer 131, there was provided a sheet obtained by annealing a foamed polyethylene sheet having a thickness of 3 mm at 80 °C for an hour in a hot-air oven.

2. As the first adhesive layer 132, there were provided an acrylic emulsion adhesive.

3. As the insulating layer 133, there was provided a PET film having a thickness of 100  $\mu\text{m}$ .

5 4. As the second adhesive layer 134, there was provided an EVA sheets having a thickness of 300  $\mu\text{m}$ .

5. As the solar cell 135, there was provided a solar cell prepared in accordance with the procedures for the preparation of the solar cell in Example 11.

6. As the reinforcing member 136, there was provided a nonwoven glass fiber member (linear diameter: 10  $\mu\text{m}$ , weighing: 80 g/m<sup>2</sup>).

10 7. As the third adhesive layer 137, there was provided an EVA sheet of 460  $\mu\text{m}$  in thickness.

8. As the surface protective layer 138, there was provided a fluororesin film of 50  $\mu\text{m}$  in thickness having a surface applied with corona discharge treatment which is to be contacted with the third adhesive layer 137.

8. Preparation of a solar cell module:

15 On a surface of an aluminum plate of 20 mm in thickness which is provided with a heater therein, there were stacked the PET film as the insulating layer 133, the EVA sheet as the second adhesive layer 134, the solar cell 135, the nonwoven glass fiber member as the reinforcing member 136, the EVA sheet as the third adhesive layer 137, and the fluororesin film as the surface protective layer 138 in the named order to form a stacked body.

20 Successively, there was superposed a heat resistant silicone rubber sheet of 3 mm in thickness on the stacked body so as to enclose the stacked body. And the space containing the stacked body between the aluminum plate and the silicone rubber sheet was sealed using an O-ring. Then, using a vacuum pump, said space containing the stacked body was vacuumed so that the inside of the stacked body became 10 mmHg. After the inside of the stacked body was sufficiently vacuumed, by energizing the heater of the aluminum plate, the stacked body was heated to 150 °C and it was maintained at this temperature for 20 minutes under condition of continuing the vacuuming operation. Thereafter, 25 while still continuing the vacuuming operation, the stacked body was cooled to room temperature. Thereafter, the inside pressure of the above-described space was returned to atmospheric pressure to obtain a vacuum-treated stacked body.

30 On the PET film as the insulating layer 133 of the resultant stacked body, the foregoing acrylic emulsion adhesive was applied by means of the conventional roll coating process, followed by drying for 10 minutes, to form a layer as the first adhesive layer 132. Successively, on the first adhesive layer 132 thus formed, the foregoing annealed sheet as the backface protective layer 131 was laminated. By this, there was obtained a solar cell module.

The constitution of the covering material of the solar cell module obtained here is substantially the same as that of the solar cell module in Reference Example 1.

The above procedures were repeated to obtain a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 11.

35 The evaluated results obtained are shown in Table 3.

#### Reference Example 10

40 The procedures of Example 11 were repeated, except that the insulating layer 133 and the second adhesive layer 134 were not formed, to thereby obtain a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 11.

The evaluated results obtained are shown in Table 3.

#### Reference Example 11

45 The procedures of Example 14 were repeated, except that the foamed polyethylene sheet having a thickness of 3 mm used as the backface protective layer 131 was used without subjecting to the anneal treatment, to thereby obtain a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 11.

50 The evaluated results obtained are shown in Table 3.

#### Additional Evaluation

55 As for each of the solar cell modules obtained in Examples 11 to 14, the layer thickness deformation proportion of the back side covering material to be deformed in terms of the layer thickness upon the application of an external pressure was examined by applying a load of 2 Kg/cm<sup>2</sup> to the back side covering material at room temperature to measure a layer thickness deformation proportion. As a result, the layer thickness deformation proportion was found to be 40% for the solar cell module obtained in Example 11, 15% for the solar cell module obtained in Example 12, 10% for the solar cell module obtained in Example 13, and 45% for the solar cell module obtained in Example 14.

Table 3

	endurance against changes in environmen- tal temperature	cushioning property	impact resistance	adhesion in envi- ronment with a high temperature and humidity
Example 11	⊙	⊙	⊙	⊙
Example 12	⊙	⊙	⊙	⊙
Example 13	⊙	○	○	⊙
Example 14	○	⊙	⊙	○
Reference Example 10	⊙	X	X	⊙
Reference Example 11	X	⊙	⊙	○

Based on the results shown in Table 3 and the examined results described in the foregoing additional evaluation, the following facts are understood. That is, the covering material of any of the solar cell modules obtained in Examples 11 to 14 (belonging to the present invention) exhibits a desirable layer thickness proportion within a specific range and excels in durability, protective ability, and adhesion even when the solar cell module is used in severe environments. On the other hand, the covering material of the solar cell module obtained Reference Example 10 is poor in protective ability and impact resistance, and the covering material of the solar cell module obtained in Reference Example 11 is poor in durability against changes in environmental temperature.

Further, as for conventional solar modules, the environment under which they can be used is limited, but any of the solar cell modules according to the present invention has no particular limitation for the use environment and they can be stably and safely used under any environment.

Now, the solar cell module according to the present invention can be widely used as a building construction member by properly designing using an appropriate support member made of, for example, a metallic material.

Herein, description will be made of an example of using the solar cell module according to the present invention as a building construction member, specifically, as a roof member with reference to FIGs. 14 to 16.

FIG. 14 is a schematic view illustrating an embodiment in that the solar cell module is designed so that it can be used as the roof member. In FIG. 14, reference numeral 1000 indicates a solar cell module designed so that it can be used as a roof member. Particularly, the solar cell module 1000 comprises a solar cell 1002 comprising a photovoltaic element enclosed by a surface side covering material and a back side covering material including the foregoing formed material layer, insulating material layer and the like, which is disposed on a support member (a reinforcing member) 1001 such as a steel plate. The support member 1001 is designed to have a greater size than that of the solar cell 1002 such that it has four externally extended portions respectively situated outside each edge of the solar cell 1002 as shown in FIG. 14.

The solar cell module 1000 shown in FIG. 14 is then processed as shown in FIG. 15, wherein the four extended portions of the solar cell module 1000 are bent toward the side opposite the light receiving face of the solar cell module. The solar cell module thus configured can be used as a building construction member, specifically, as a roof member.

FIGs. 16(A) and 16(B) are schematic views illustrating an embodiment of placing the solar cell module shown in FIG. 15 on a roof of a building as a roof member.

As shown in FIG. 16(A), the solar cell module 1000 is arranged on receiving members 1010 fixed to a roof plate 1020 by means of bolts 1030, then the solar cell module is pressed from above, whereby the bent extended portions of the solar cell module are engaged in the receiving member 1010.

FIG. 16(B) is a schematic view illustrating a cross-sectional structure of a configuration in that a plurality of solar cell module each comprising the solar cell module shown in FIG. 15 are placed on a roof of a building, wherein each adjacent extended portions of the given two solar cell modules 1000 and 1100 are engaged in the common receiving member 1010.

In the following, description will be made of advantages of the present invention.

As previously described, the solar cell module has, on the side opposite the light receiving face side, the specific covering material (that is, the back side covering material) capable of deforming at a layer deformation proportion of 5 to 75% against a load of 2 Kg/cm<sup>2</sup> applied at room temperature and because of this, the photovoltaic element (the solar cell) contained in the solar cell module is always maintained in a stable state without being damaged even when the solar cell module is placed on an irregular surface of sandy plain, sandy beach, or the like and unexpected external pressure, which is caused, for instance, when somebody steps thereon, is applied thereon. In addition, the back side covering material has a sufficient endurance against changes in environmental temperature and is free of the occur-

rence of layer separation even when the solar cell module is maintained in the environment with frequent changes in temperature over a long period of time. Particularly, the back side covering material is hardly deformed, for instance, when the temperature of the environment in which the solar cell module is maintained is changed from more than 30 °C to room temperature, wherein the solar cell module is always maintained in a stable state without the occurrence of layer separation in the back side covering material.

Further, as previously described, because the back side covering material has the specific foamed material layer having a desirable flexibility, it is possible to reduce the amount of the hard resin layer used. This enables to lighten a solar cell module obtain. And by making the foamed material layer to compose of a resin having a glass transition temperature (Tg) of -50 to 80 °C, the lamination process by way thermocompression bonding can be desirably conducted without damaging the foamed material layer.

In addition, by conducting the lamination of the back side covering material to the photovoltaic element (the solar cell) by way of heat treatment and successive compression treatment, the back side covering material becomes to have a sufficient heat history and because of this, heat contraction or the like are not occurred at the back side covering material. When the compression treatment is conducted by way of vacuum compression treatment, the size of an equipment to be used therefor can be minimized.

Further, by conducting the heat treatment in the lamination process at a temperature of 80 to 200 °C, the occurrence of negative influences to the photovoltaic element (the solar cell) and the back side and surface side covering materials can be minimized. In this case, by making the period of time for the heat treatment to be 2 hours or less, the period of time required to accomplish the lamination process can be shortened while minimizing the occurrence of negative influences to the photovoltaic element (the solar cell) and the back side and surface side covering materials due to the heat treatment.

A solar cell module which comprises a stacked body a photovoltaic element interposed between a surface side covering material and a back side covering material having a foamed material layer, wherein said foamed material layer is a layer formed by foaming a nonfoamed material during the formation of said stacked body. And a building construction member having said solar cell module.

#### Claims

1. A solar cell module comprising a photovoltaic element having a photoactive semiconductor layer as a photoelectric conversion member, said photovoltaic element being enclosed by a surface side covering material disposed to cover the light receiving face side of said photovoltaic element and a back side covering material disposed to cover the rear face side of said photovoltaic element, and said back side covering material comprising a foamed material, characterized in that said foamed material comprises a member (a) selected from the group consisting of a stacked body (a-i) comprising a foamed material and a fiber or a material (a-ii) comprising a foamed material incorporated with a fiber therein.
2. A solar cell module according to claim 1, wherein the fiber is a woven fabric or a nonwoven fabric.
3. A solar cell module according to claim 1, wherein the back side covering material contains the member (a) such that the backface side covering material has a substantially smooth surface.
4. A solar cell module according to claim 1, wherein the back side covering material has a stacked structure comprising a first adhesive layer, an insulating material layer, a second adhesive layer, and the member (a) laminated in the named order, and said second adhesive layer has a crosslinked molecular structure.
5. A solar cell module according to claim 1, wherein the foamed material of the stacked body (a-i) or the material (a-ii) has a crosslinked molecular structure.
6. A solar cell module according to claim 1, wherein the surface side covering material has a surface protective layer comprising a fluororesin.
7. A solar cell module according to claim 1, wherein the amount of the fiber contained in the stacked body (a-i) or the material (a-ii) is in the range of from 0.5 to 20 parts by weight versus the amount of the foamed material.
8. A solar cell module according to claim 1, wherein the foamed material of the stacked body (a-i) or the material (a-ii) comprises a closed bubble.
9. A solar cell module according to claim 1, wherein the back side covering material is disposed on a base member.

10. A solar cell module according to claim 9, wherein the base member is a steel plate.
11. A solar cell module according to claim 1, wherein the back side covering material comprising the member (a) has a layer thickness deformation proportion of 5 to 75% against a load of 2 Kg/cm<sup>2</sup> applied thereon at room temperature.
12. A process for producing a solar cell module comprising a photovoltaic element having a photoactive semiconductor layer as a photoelectric conversion member which is enclosed by a surface side covering material disposed to cover the light receiving face side of said photovoltaic element and a back side covering material disposed to cover the rear face side of said photovoltaic element, said process includes a step of covering the rear face side of said photovoltaic element by said back side covering material, said step comprising providing a nonfoamed material containing a foaming agent therein usable as a constituent of said backface side covering material, and decomposing said foaming agent contained in said nonfoamed material to form a foamed material in said back side covering material.
13. The process according to claim 12 which includes a step of preventing a gas generated during the formation of the foamed material from leaking to the outside.
14. The process according to claim 12 which includes a step of forming a laminate as the back side covering material on the backface side of the photovoltaic element by sequentially laminating an insulating member, the nonfoamed material and a base member in the named order on the backface side of the photovoltaic element prior to the formation of the foamed material, wherein the size of each of the insulating member and the base member before forming the laminate on the backside face of the photovoltaic element is made to be greater than that of the nonfoamed material.
15. The process according to claim 12, wherein the covering of the photovoltaic element by the surface side covering material and the back side covering material is conducted by way of vacuuming process.
16. The process according to claim 12 which includes a step comprising providing a stacked body comprising the surface side covering material, the photovoltaic element, and the back side covering material and subjecting the stacked body to vacuuming treatment.
17. The process according to claim 12 which includes a step of laminating the back side covering material containing the nonfoamed material, the photovoltaic element, and the surface side covering material in the named order.
18. The process according to claim 12, wherein the back side covering material further contains a fiber.
19. The process according to claim 18, wherein the backface side covering material further contains an adhesive material.
20. The process according to claim 18 which includes a step of forming a stacked body by laminating the backface side covering material containing the nonfoamed material and the fiber, the photovoltaic element, and the surface side covering material in the named order on a lamination instrument provided with a releasing material.
21. The process according to claim 19 which includes a step of forming a stacked body by laminating the backface side covering material containing the nonfoamed material and the fiber and the adhesive material, the photovoltaic element, and the surface side covering material in the named order on a lamination instrument provided with a releasing material.
22. The process according to claim 21, wherein the stacked body formed on the lamination instrument is subjected to vacuuming treatment while sealing the stacked body by the aid of the adhesive material thereby obtaining a sealed stacked body and the sealed stacked body is released from the lamination instrument by the aid of the releasing material.
23. The process according to claim 22, wherein the releasing material has a nitrogen permeability of  $1.0 \times 10^4$  cm<sup>3</sup>/(m<sup>2</sup>.24h.atm) and a surface having a melting point of 150 °C or above.
24. The process according to claim 16, wherein a rigid plate is disposed on the stacked body.

25. A solar cell module comprising a photovoltaic element having at least a photoactive semiconductor layer as a photoelectric conversion member and having a light receiving face and a backface opposite said light receiving face, said photovoltaic element having a covering material on at least the backface side of said photovoltaic element, characterized in that said covering material has a layer thickness deformation proportion of 5 to 75% against a load of 2 Kg/cm<sup>2</sup> applied thereon at room temperature.
26. A solar cell module according to claim 25 which is durable against changes in environmental temperature of 30 °C or above.
27. A solar cell module according to claim 25, wherein the covering material has at least a layer containing a foamed material therein.
28. A solar cell module according to claim 27, wherein the foamed material comprises a resin having a glass transition temperature (T<sub>g</sub>) of -50 to 80 °C.
29. A process for producing a solar cell module having at least a photoactive semiconductor layer as a photoelectric conversion member and having a light receiving face and a rear face opposite said light receiving face, said photovoltaic element having a covering material on at least the backface side of said photovoltaic element, and said covering material having a layer thickness deformation proportion of 5 to 75% against a load of 2 Kg/cm<sup>2</sup> applied thereon at room temperature, said process includes steps of laminating said covering material to the backface of said photovoltaic element, subjecting the resultant to compression treatment, followed by subjecting to heat treatment.
30. The process according to claim 29, wherein the covering material has at least a layer containing a foamed material therein.
31. The process according to claim 30, wherein the foamed material comprises a resin having a glass transition temperature (T<sub>g</sub>) of -50 to 80 °C.
32. The process according to claim 29, wherein the heat treatment is conducted at a temperature of 80 to 200 °C.
33. The process according to claim 29, wherein the heat treatment is conducted for 2 hours or less.
34. The process according to claim 29, wherein the compression treatment is conducted by way of vacuum compression treatment.
35. A building construction member having a solar cell module comprising a photovoltaic element having a photoactive semiconductor layer as a photoelectric conversion member, said photovoltaic element being enclosed by a surface side covering material disposed to cover the light receiving face side of said photovoltaic element and a back side covering material disposed to cover the rear face side of said photovoltaic element, and said back side covering material comprising a foamed material, characterized in that said foamed material comprises a member (a) selected from the group consisting of a stacked body (a-i) comprising a foamed material and a fiber or a material (a-ii) comprising a foamed material incorporated with a fiber therein.
36. A building construction member according to claim 35, wherein the member (a) has a layer thickness deformation proportion of 5 to 75% against a load of 2 Kg/cm<sup>2</sup> applied thereon at room temperature.
37. A building construction member having a solar cell module comprising a photovoltaic element having at least a photoactive semiconductor layer as a photoelectric conversion member and having a light receiving face and a backface opposite said light receiving face, said photovoltaic element having a covering material on at least the backface side of said photovoltaic element, characterized in that said covering material has a layer thickness deformation proportion of 5 to 75% against a load of 2 Kg/cm<sup>2</sup> applied thereon at room temperature.
38. A roof building having a solar cell module comprising a photovoltaic element having a photoactive semiconductor layer as a photoelectric conversion member, said photovoltaic element being enclosed by a surface side covering material disposed to cover the light receiving face side of said photovoltaic element and a back side covering material disposed to cover the rear face side of said photovoltaic element, and said back side covering material comprising a foamed material, characterized in that said foamed material comprises a member (a) selected from the group consisting of a stacked body (a-i) comprising a foamed material and a fiber or a material (a-ii) comprising a foamed

material incorporated with a fiber therein.

39. A roof member having a solar cell module comprising a photovoltaic element having at least a photoactive semiconductor layer as a photoelectric conversion member and having a light receiving face and a backface opposite said light receiving face, said photovoltaic element having a covering material on at least the backface side of said photovoltaic element, characterized in that said covering material has a layer thickness deformation proportion of 5 to 75% against a load of 2 Kg/cm<sup>2</sup> applied thereon at room temperature.

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FIG. 1(A)

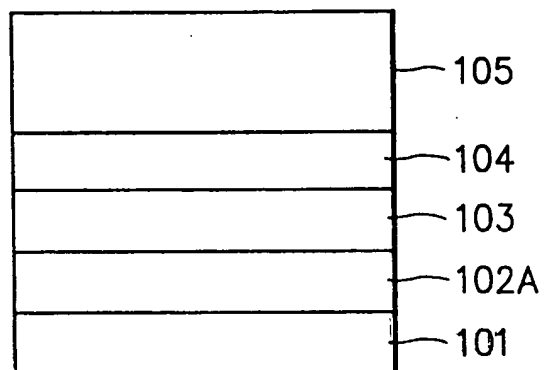


FIG. 1(B)

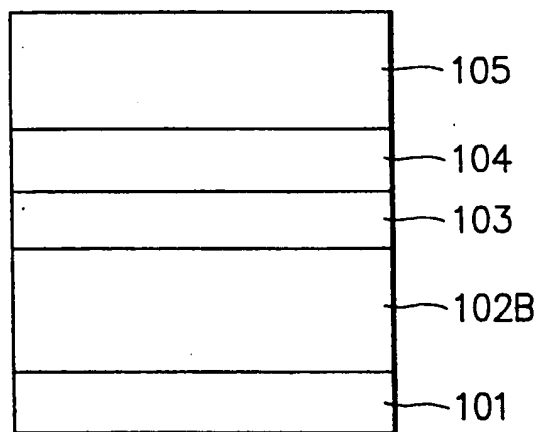


FIG. 2(A)

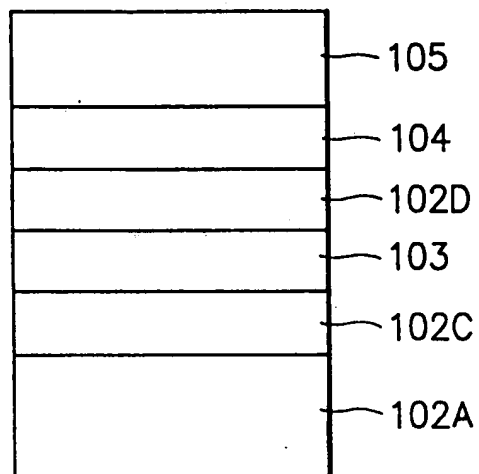


FIG. 2(B)

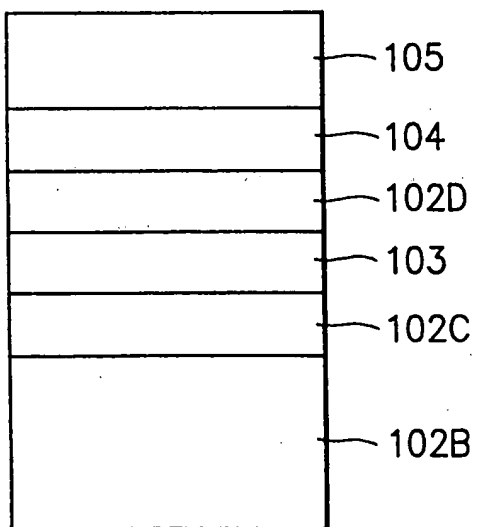




FIG. 3

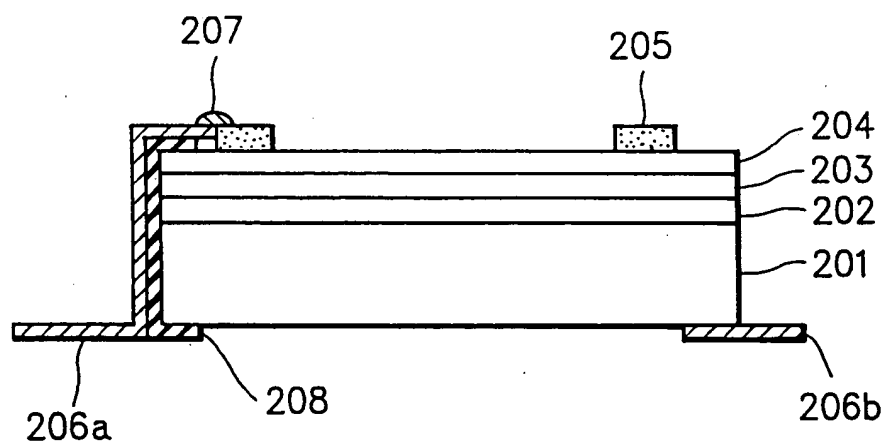


FIG. 4

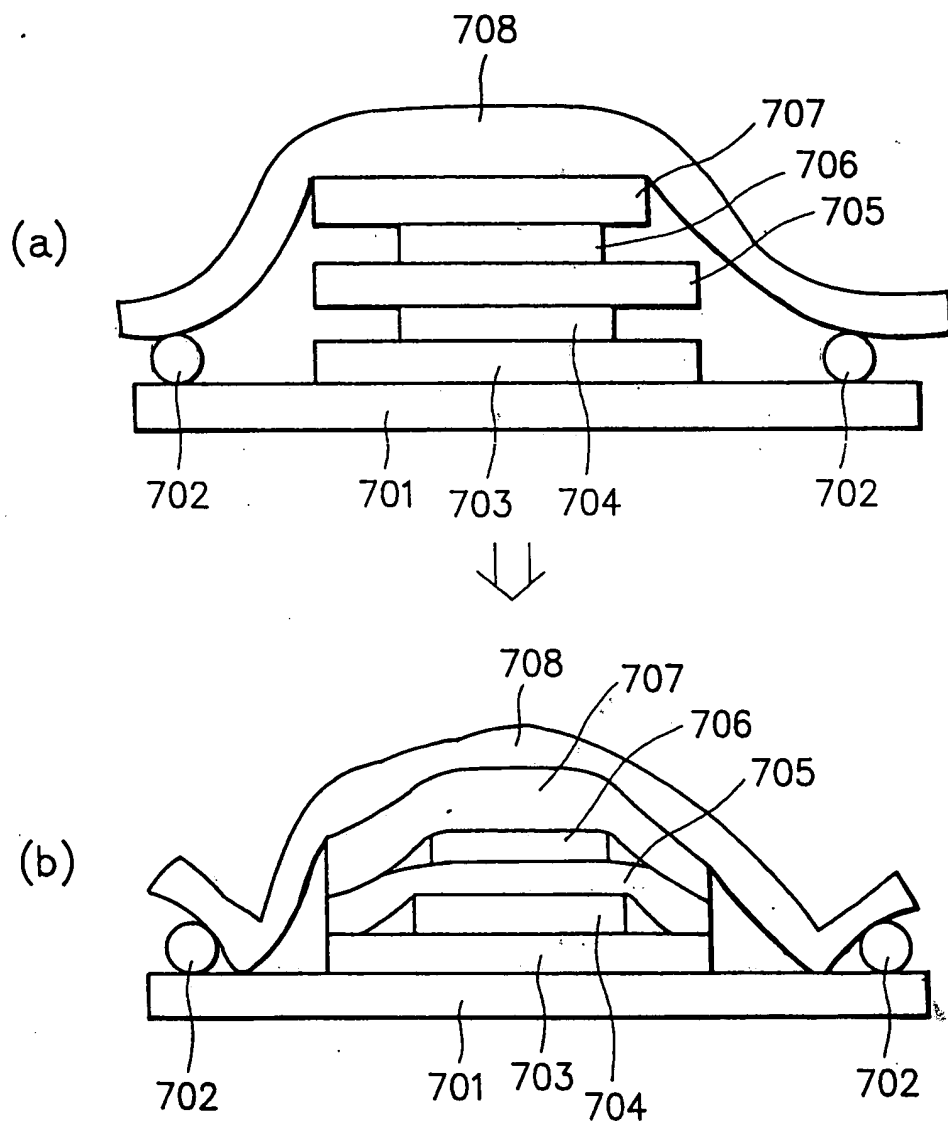


FIG. 5

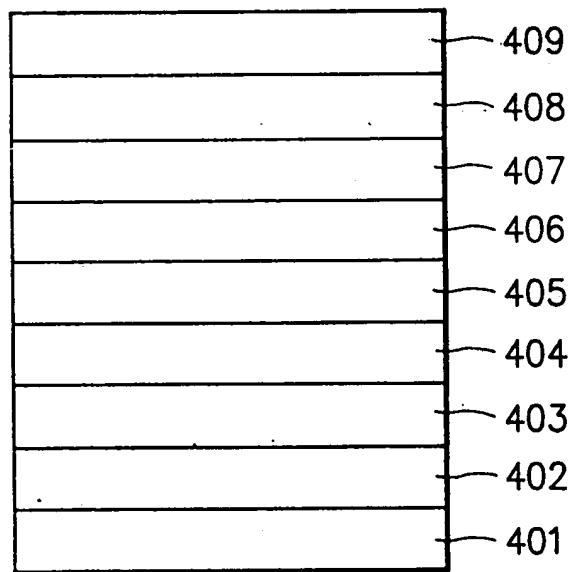


FIG. 6(A)

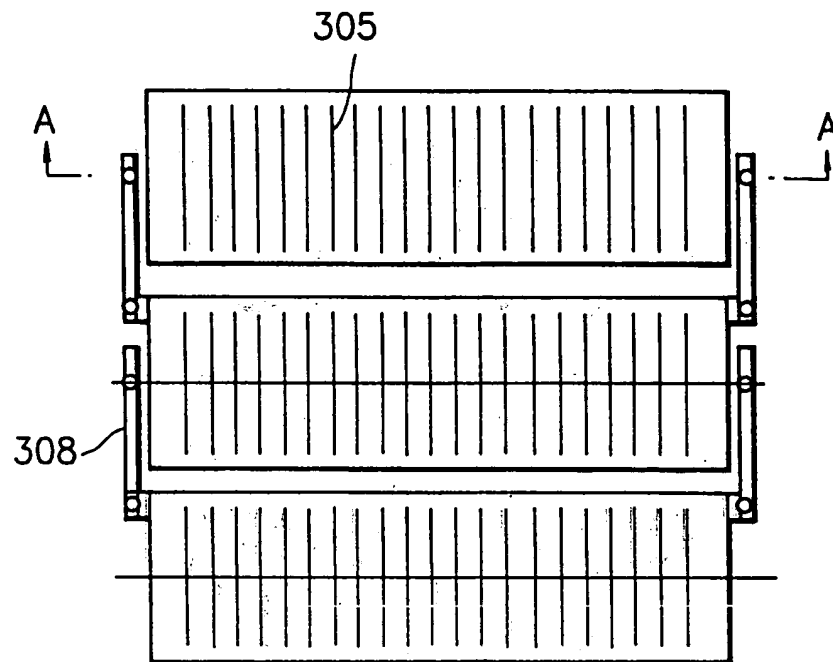


FIG. 6(B)

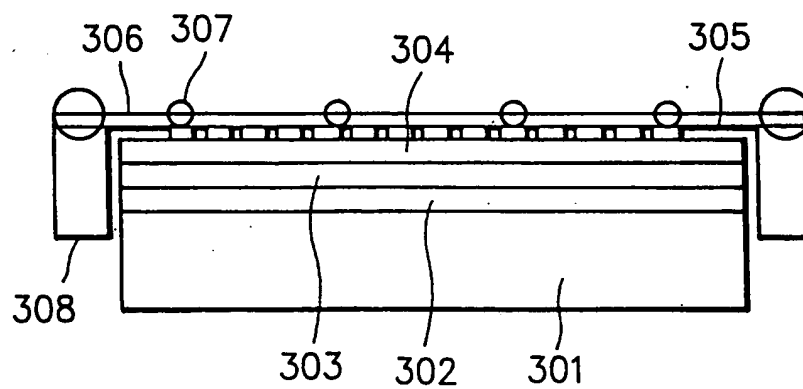


FIG. 7

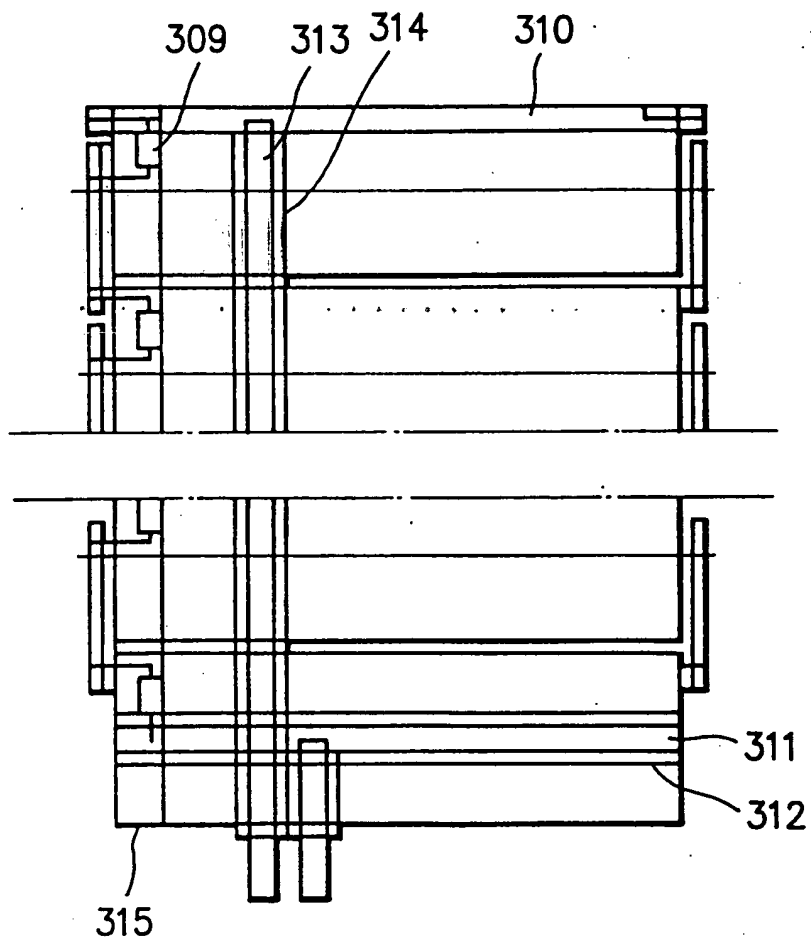


FIG. 8

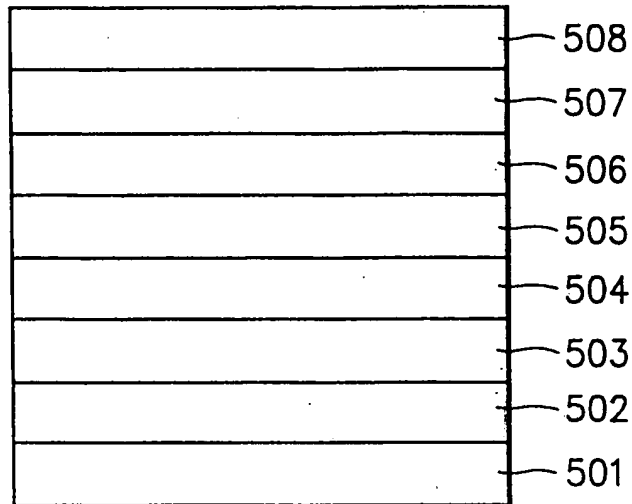


FIG. 9

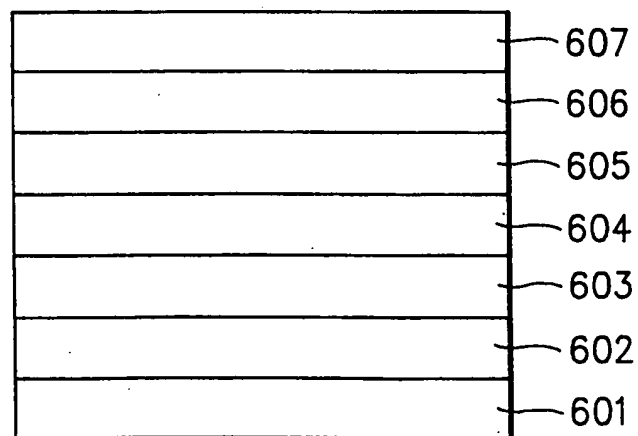


FIG. 10

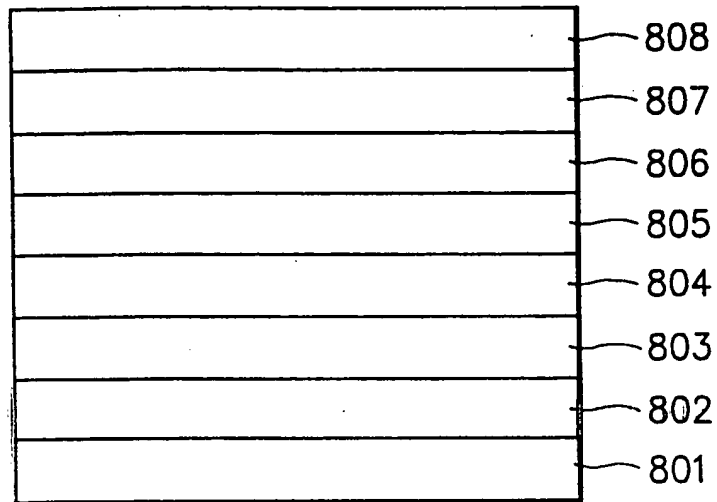


FIG. 11

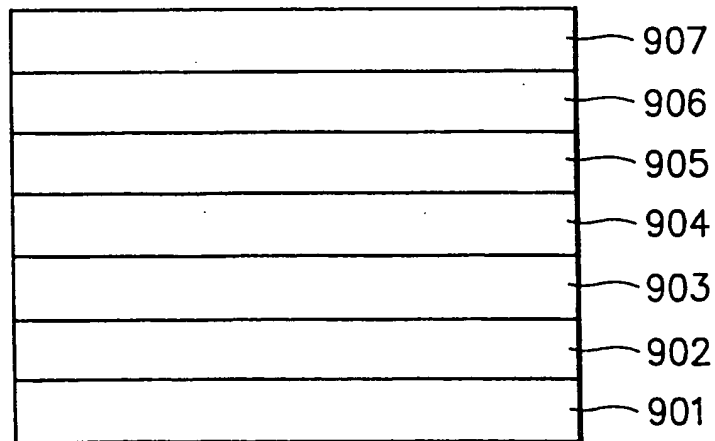


FIG. 12

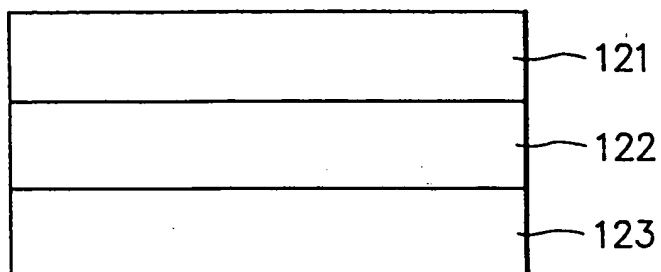


FIG. 13

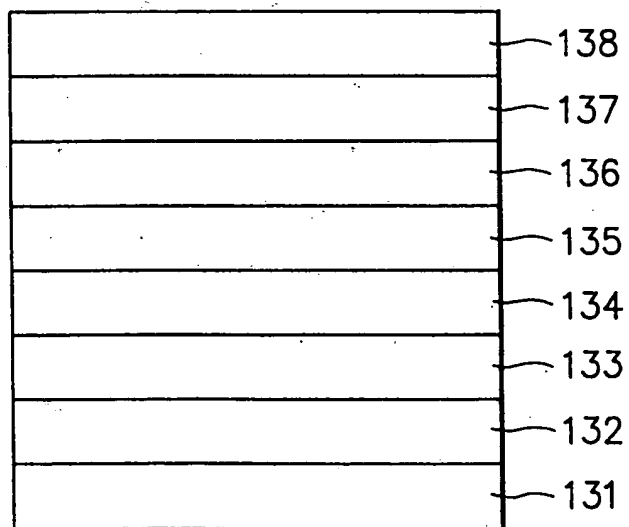




FIG. 14

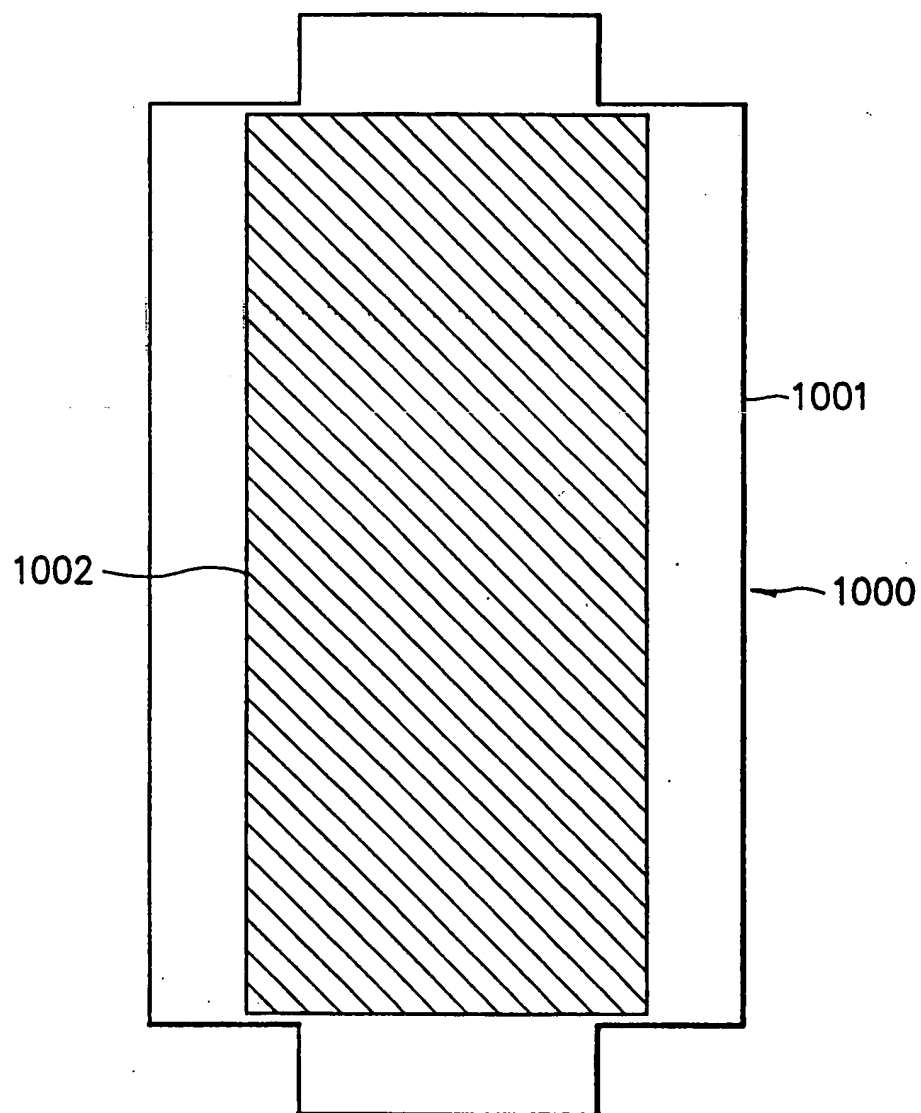


FIG. 15

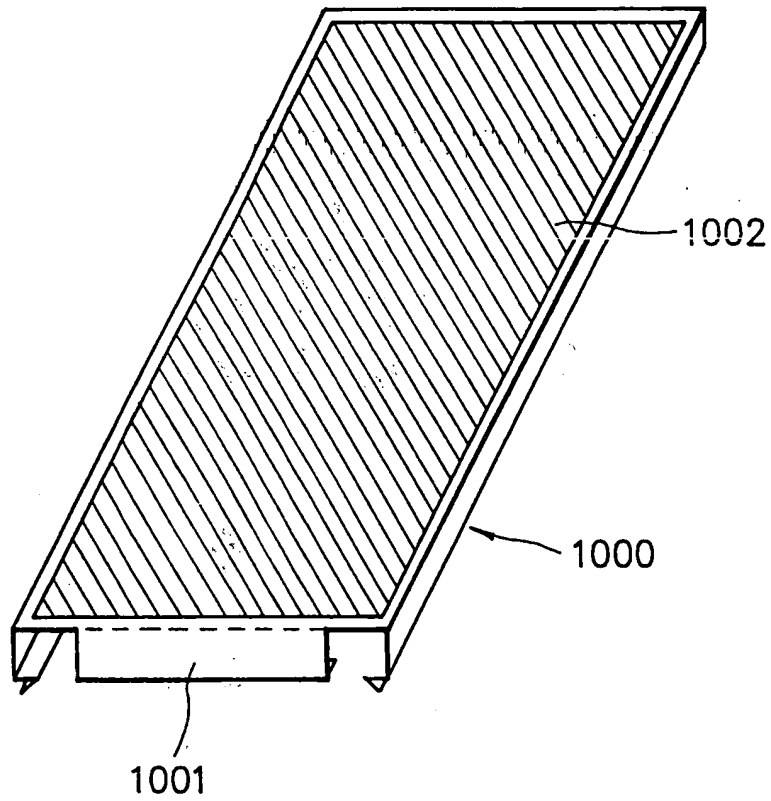


FIG. 16 (A)

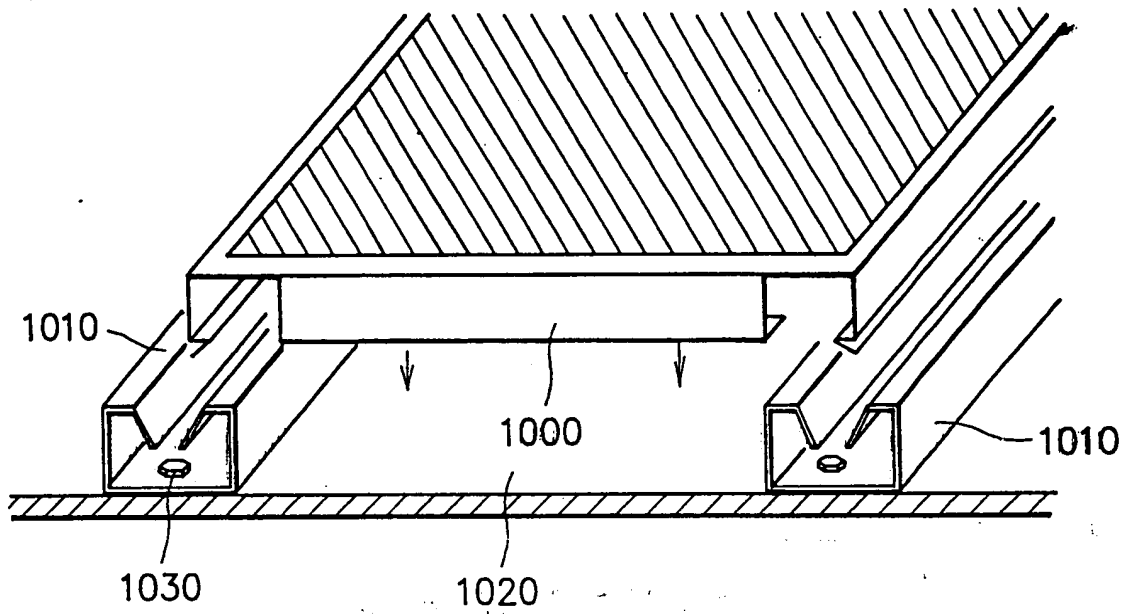
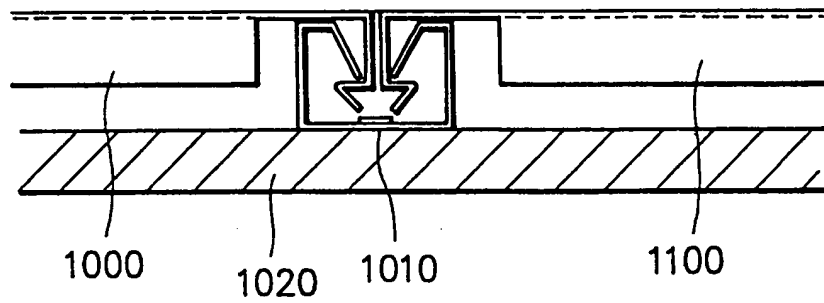


FIG. 16 (B)



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(11)

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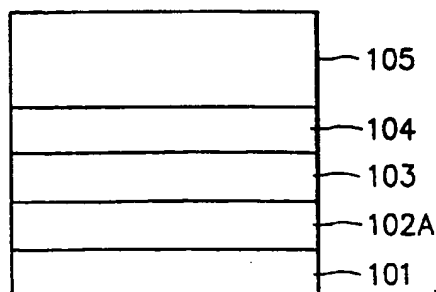
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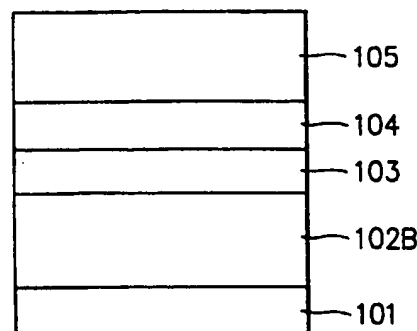
(54) **A solar cell module having a specific back side covering material and a process for the production said solar cell module**

(57) A solar cell module which comprises a stacked body of a photovoltaic element (104) interposed between a surface side covering material (105) and a back side covering material having a foamed material layer (102B), wherein said foamed material layer is a layer formed by foaming a nonfoamed material (102A) during the formation of said stacked body. And a building construction member having said solar cell module.

**FIG. 1(A)**



**FIG. 1(B)**



**EP 0 762 514 A3**



European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number  
EP 96 11 3641

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	DE 35 20 424 A (TELEFUNKEN ELECTRONIC GMBH) 11 December 1986 * column 2, line 39 - column 3, line 13; figure 1 *	1-3,5,25	H01L31/048 E04D13/18
A	EP 0 325 369 A (ATLANTIC RICHFIELD CO) 26 July 1989 * column 8, line 8 - line 20 * * column 10, line 5 - line 24; figure 2 *	12-17,29	
A	DE 43 01 404 C (LENZ MICHAEL C) 28 July 1994 * column 1, line 55 - column 2, line 3 * * column 2, line 54 - column 3, line 3; figure 1 *	1-4,9	
A	US 5 409 549 A (MORI MASAHIRO) 25 April 1995 * column 6, line 1 - line 36 *	35-39	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H01L
The present search report has been drawn up for all claims			
Place of search <b>THE HAGUE</b>		Date of completion of the search <b>16 November 1998</b>	Examiner <b>Acco, S</b>
<p><b>CATEGORY OF CITED DOCUMENTS</b></p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			

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